Hospital Specialization and Hospital Charge, Length of Stay, and Mortality for Lumbar Spine Disease Inpatients

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ABSTRACT

Hospital Specialization and Hospital Charge, Length of Stay, and Mortality for Lumbar Spine Disease Inpatients

Background: In South Korea, notable recent health policy changes such as designation of specialty hospitals and implementation of diagnosis related groups (DRGs) have occurred, hospitals have begun exploring and planning specialization strategies in order to achieve competitive advantage and attract more patients. Thus, precise, valid, and reliable measures of hospital specialization for competitive advantage have become increasingly necessary. However, there exist various limitations on the case-mix hospital specialization index based on patient proportion. Thus, the purpose of this study is to modify the category medical specialization index and to investigate the association between this modified category medical specialization index and length of stay (LOS), mortality, and hospital charge.

Methods: A representative national sample dataset provided by the National Health Insurance Service–Cohort Sample Data (NHIS-CSD) for 12 years, 2002 to 2013, was employed. To extract lumbar spine disease patients within hospitals from these data, diseases were classified into 267 categories based on the International Classification of Diseases, Tenth Revision (ICD-10). Modified Category Medical Specialization (Modified CMS) was incorporated into log transformation to the denominator of CMS, to reduce between-hospital variation in number of medical categories. Associations with LOS, mortality, hospital cost per case and hospital cost per diem. This study included 56,622 cases; the primary analysis was based on a generalized estimating equation (GEE) regression model accounting for correlation among hospitals within each region to examine our hypothesis.

Results: Our modified CMS shows a U-shaped trend of hospital specialization from small to large hospitals, with excellent goodness-of-fit. Among lumbar spine disease surgery patients, the adjusted effects of association between modified CMS and length of stay, mortality, hospital cost per case, and total cost per diem show that LOS in hospitals with high modified CMS was -2.539 days shorter (p: <.0001), mortality of hospitals with high modified CMS was 0.972 times lower (p: 0.715), total cost per case of hospitals with high modified CMS was -152,060 won lower (p: <.0001), and total cost per diem of hospitals with high modified CMS was -42,362 won higher (p: <.0001).

Conclusions: To our knowledge, this is the first study to develop and implement modified CMS for a specific disease (lumbar spine disease). The results show that increase in hospital specialization has a substantial effect on decrease in hospital costs per case, LOS, mortality, and increase in hospital cost per diem. Therefore, in the context of increasing competition and recent policy changes by the Korean government, our results may help Korean and non-Korean hospital policymakers understand the effects of hospital specialization strategy on hospital profitability and efficiency.

Key words: hospital, specialization, hospital charge, length of stay, mortality, efficiency

I. Introduction

Over the last few decades, hospitals in South Korea also have undergone dramatic changes, such as increasing specialization and implementation of diagnosis related groups (DRGs). Korean hospitals traditionally have provided a broad range of health care services in the health care market; the changes mentioned above occurred after the implementation of incentives for efficiency[1] and as providers faced increasing financial challenges[1] due to an increase in the number of small general hospitals, from 581 in 2000 to 1,064 in 2008.[2] To respond to such changes, small general hospitals increasingly specialized in certain medical services to better compete with other small and mid-sized hospitals[2] as "specialty hospitals," and an effort emerged among these institutions to promote the development of "superb small general hospitals"[2] through investment in high-tech equipment. Thus, in recent times in Korea, a rapid rise in the number of small hospitals specializing in spinal, cardiac, orthopedic, and surgery services occurred.[3]

Furthermore, health care market conditions have changed dramatically in recent years. Prescription and drug dispensing for outpatients, once performed in hospitals, was once a major source of revenue, but in 2000, the Korean government enacted new laws that separated prescription and drug dispensing; now all outpatients must purchase drugs from outside pharmacies. In addition, the implementation of the DRG system for hospitals and clinics became mandatory on July 1, 2012 and for general and tertiary hospitals on July 1, 2013. These changes in the payment mechanisms for hospital care affected competition among hospitals,[4,5] primarily on the axes of hospital performance and quality of care.[6,7] That is, in response to the new payment system, hospitals adopted various cost-saving strategies and changed their medical health behavior.

Meanwhile, in US hospitals, the most notable change in recent memory occurred in 1983 when the national Medicare health insurance scheme implemented a prospective payment system (PPS) under which most hospitals receive a prospectively determined fixed payment per patient; this meant that hospitals could no longer be financially indifferent to inter-hospital rivalry and that treatment could no longer be straightforwardly based on the actual costs the hospital incurred to treat a patient. While hospitals receiving cost-based reimbursement had not needed to worry about maintaining a high occupancy rate or about attracting more patients to cover their sizable fixed costs, under prospective payment they had to compete for patients or see payments fall accordingly. Thus, the introduction of prospective payment engendered unprecedented competition among hospitals for patients, and the health care services industry has faced a turbulent environment as a result.[8]

In both South Korea and the US, with increasing between-hospital competition, hospitals have begun exploring and planning hospital specialization strategies for differentiation, concentration, and competitive advantage, to attract more patients. The changes in reimbursement structure have also affected the behavior of hospitals in other ways. One anticipated response is an increase in inpatient case-mix patients[9] to reduce the average cost of a hospital admission by shortening length of stay (LOS) and, in some instances, providing fewer services per case.[10-12] In addition, on the basis of "quality of care improvement," hospitals have adopted new services and equipment to attract and retain physicians and patients.[13-16]

A broad range of findings in economic theory show that competition will eventually lead hospitals to reduce the services they offer, because they will concentrate on services for which they have a comparative advantage and will reduce or eliminate other services that their competitors can provide more efficiently. The idea that hospital specialization can improve performance and efficiency has a long history, dating back to Smith and his work on the division of labor[17]; Taylor similarly proposed enhancing organizational performance by deploying workers based on their individual skills.[18] Whereas both Smith and Taylor focused on individual specialization, concentrating in particular on individual activities, March and Simon emphasized the need to differentiate between individual and higher-level specialization.[19] Thus, exact measures of hospital specialization for competitive advantage have become increasingly necessary. Traditionally, the most common of these measures in the hospital context has been the Information Theory Index (ITI),[10,20,21] used by Eastaugh to explain differences in costs among hospitals in a given region[22,23] and by Linna and Häkkinen,[24] Lee et al.,[1] and Herwartz and Strumann[4] to explain differences in hospital efficiency. It was developed by Farley[21] and Farley and Hogan[23] to analyze to what degree hospitals had become more “unusual” over time. Farley and Hogan used an index of service derived from information theory that, in essence, depends on the differences between the proportion of discharges in the services provided by a given hospital and the average proportions for all hospitals in a given country or region. They also defined a second measure, based on the work of Baumgardner and Marder,[25] interpreting “specialization” as doing a narrow range of things[25] and thus using the inner Herfindahl–Hirschman Index (IHI). These measures analyze hospital caseloads based on patient proportions, independent of patient volumes. This means that the total number of patients treated is effectively normalized to 100%.

However, traditional measures of specialization such as IHI and ITI fail to account for important issues. First, relying solely on patient proportions might be problematic for larger hospitals that provide a high number of diagnosis categories, as the patient proportions in each category are naturally relatively smaller in such hospitals. For instance, using a measure of hospital specialization based on patient proportions, Dayhoff and Cromwell[26] found that specialization decreased as hospital size and the number of diagnosis-related groups increased. This suggests that traditional measures of specialization such as IHI and ITI do not truly capture hospital specialization. In particular, both small and large hospitals may treat a large number of patients in multiple diagnosis categories, which might be associated with a high level of experience, professional expertise, and technical equipment. Thus, measuring specialization at these institutions based on case-mix specialization, as with IHI and ITI, may lead to a result showing inappropriately low specialization for a practice as a whole in cases where several physicians are providing a heterogeneous range of specialties.

Second, ITI is a somewhat paradoxical measure of specialization, since it is large if the hospital provides either a broader- or a narrower-than-average mix of service. That is, this measure captures only the magnitude of a hospital's differentiation, not the direction. However, a hospital with a high ITI may be specialized in the sense that it is unusual, but not necessarily in the sense that it has a concentrated service mix, and so this measure does not capture the distinction between concentrating on an unusually small range of services and the opposite strategy of expanding services to develop a broader mix than is typical. Therefore, the present study used two recently developed novel measures of hospital specialization: category medical specialization (CMS) and inner category medical specialization (ICMS); these are based on patient volumes rather than patient proportions,[27] which were measured by both IHI and ITI. These newly developed measures can thus be conceptually contrasted to the typically used "case-mix" specialization measures.

Finally, to date, hospital specialization measures as a case-mix index of hospital level, could not identify the extent of specialization in a specific medical category within a hospital.[28] To address this issue, this study developed "modified category medical specialization" (modified CMS).

II. Objectives

The purpose of this study was to modify category medical specialization and to examine the impact of the modified category medical specialization on LOS, mortality, hospital cost per case, and hospital cost per diem among lumbar spine disease inpatients.

The detailed objectives of this study were as follows:

(1) To examine the distribution of hospital specialization score by each hospital specialization measure and by hospital size;

(2) To examine hospital patient distribution by proportion and absolute number of lumbar spine patients; and

(3) To investigate any association between (modified CMS and LOS, mortality hospital cost per case, hospital cost per diem among lumbar spine disease inpatients.

III. Literature Review

1. Definition of Hospital Specialization

Economists have pointed out the advantages of specialization going back to Adam Smith's portrayal of a hypothetical factory producing nails. However, in contrast to the implications of Smith's depiction, many hospitals continue to provide a wide range of services. Some analysts argue regarding this phenomenon that such hospitals are anachronisms, and that the introduction of market forces into health care will likely create hospitals that are "specialized factories," and will outcompete traditional ones.[29] In fact, these focused factories, whether inpatient (specialty hospitals) or outpatient (ambulatory surgery centers), may provide higher-quality health care at a lower cost and yield higher patient satisfaction by dedicating staff, equipment, and management attention to the treatment of a particular disease type. Yet despite the relatively numerous speculations on enhanced specialization, few discussions have been taken place about what "specialization" essentially denotes in the health care facility context and how it can be measured.

"Case-mix specialization" denotes the combination of inpatient services in a hospital's output. It is defined by the extent to which its proportions deviate from what may be considered "normal." That is, this factor increases as hospitals begin to look less similar, reflecting the intuitive notion that specialization is reduced as hospitals tend to produce the same combination of inpatient services. Thus, naturally, means that at the other extreme, the most specialization is considered to take place when each hospital is the only provider of certain services.

It is essential that this definition be distinguished from the concept of "specialized services" or "specialized" hospital units, which usually indicate medical care or resources that require sophisticated technology or atypical professional expertise. In contrast, the addition of a trauma center or a pediatric intensive care unit can increase the case-mix specialization of a hospital under the present definitions, as a larger number of patients are admitted in rather rare diagnostic groups.

Reflecting the discussion above, our definition of specialization does not rest solely on technological sophistication or special professional expertise. Hospitals can provide treatments in several different diagnosis categories and may have personnel who medically specialize in each of them, independently of the hospital's degree of institutional-level diversification. However, most hospital specialization has used information on proportion of diagnoses in different categories—thus indirectly assuming that these categories are dependent on one other. Based on this assumption, we define hospitals as more specialized if the number of treated cases in a given diagnosis category exceeds a defined threshold. In short, we focus on the volume of patients in each diagnosis category and on that of patient proportions in each hospital.

2. Hospital Specialization Measures

(1) IHI (Inner Herfindahl–Hirschman Index)

Zwanziger, Melnick, and Rahmian[30] construct an inner Herfindahl index using the sum of the squares of the discharges from a disease category viewed as a proportion of all discharges from the hospital. This measure is analogous to the inner Herfindahl index used to measure market concentration; however, in Zwanziger et al.'s application, it measures the concentration of cases within a hospital. A hospital with all of its discharges in one disease category would have a value of one; the lower bound is determined by the number of disease category used in the analysis.

$$IHI = \sum_{i=1} \left(P_i{}^2\right)$$

where

P_i = proportion of the hospital`s discharges accounted for by the i^{th} disease category.

(2) ITI (Information Theory Index)

Farley[31] and Farley and Hogan[10] calculate an information theory index (ITI) to measure hospital specialization following Theil.[20] The index is a weighted log of a hospital's disease category proportions compared to national disease category proportions. Disease categories more commonly treated in a given hospital are weighted more heavily than less common disease categories. The resulting index number is equal to zero if no specialization occurs (if the hospital proportions equal the national proportions for all disease categories), and increases as the level of specialization becomes greater (as the hospital proportions diverge more from the national proportions). Thus, the ITI measures a hospital as more "specialized" as its caseload deviates more from that of the typical hospital. Therefore, hospitals that treat either a very narrow or a very broad range of cases will tend to have relatively high index values, meaning that, for instance, an unsophisticated hospital treating only the simplest cases and offering few services could have the same index value as a tertiary care hospital. A serious drawback of the ITI is this inability to distinguish between these two types of "specialization."

$$\text{ITI} = \sum_{i=1} P_i * \ln(\frac{P_i}{\theta_i})$$

where

P_i= proportion of the hospital's discharge accounted for by the i^{th} disease category;

θ_i = national average of proportions θ_i>0 of patients in each diagnosis category i;

and

ln[*] = natural log of relative hospital specialization.

(3) CMS (Category Medical Specialization)

Hospital i can be identified as a specialized hospital only if a defined minimum number of treatments ψj is reached in category j. To avoid disadvantaging smaller hospitals, we define specialization in category j as the case where more than 80% of patients treated are in that category.

$$\text{CMS} = \frac{\sum_{i=1}^{I} \varsigma_{ij}}{\sum_{i=1}^{I} \eta_{ij}}$$

with $\varsigma_{ij} = 1$ if $n_{ij} \geq \psi_{ij} or\ P_{ij} \geq 0.8,\ otherwise\ 0$

$\eta_{ij} = 1$ if $P_{ij} \geq 1/22, otherwise\ 0$

where

ψ_i = mean number of patients treated nationally in category j.

η_{ij} = a hospital has a valid diagnosis category η_{ij} if the proportion of overall patients treated who are in that category is greater than 1/22. This threshold was chosen to avoid bias due to outliers or rare cases in a hospital.

(4) ICMS (Inner Category Medical Specialization)

To consider the degree of specialization within each diagnosis category, a second specialization measure is needed; we call it inner category medical specialization (ICMS):

$$\mathrm{ICMS} = \frac{\sum_{i=1}^{I} \varsigma_{ij} * \kappa_{ij}}{\sum_{i=1}^{I} \eta_{ij}}$$

where

κ_{ij} = the category concentration (inner Herfindahl-Hirschman Index) of category *j* in hospital *i*, used as a weight.

(5) Modified CMS (Modified Category Medical Specialization)

To extract lumbar spine disease patients within each hospital, diseases were classified into 267 categories based on the International Classification of Diseases, Tenth Revision (ICD-10). It takes a log transformation to the denominator of CMS to reduce between-hospital variation of number of medical categories, because maximum disease category is up to three to extract specific disease regardless of the scale of the hospital (type, number of beds, etc.).

$$\text{Modified CMS} = \frac{\sum_{i=1}^{I} \varsigma_{ij}}{\ln(\sum_{i=1}^{I} \eta_{ij})}$$

Where

ln(*) = Natural log of what hospital has a valid diagnosis category η_{ij} if the proportion of treated patients is greater than 1/267 (number of disease categories).

3. Pros and Cons of Hospital Specialization

Hospital specialization cannot be seen as an entirely new phenomenon. For decades, hospitals centered on treating children or psychiatric patients have existed, for instance. Regarding the implications of hospital specialization for social welfare, there have been numerous debates, and many studies have explored the advantages and disadvantages of hospital specialization in the United States, investigating the effect of specialty hospitals on quality of care, cost, and the well-being of neighboring hospitals in the process.[32,33]

In the course of these debates, several issues of long-standing interest to economists have proved to be of relevance. For example, people against hospital specialization argue that they are a vehicle for blind kickbacks to physicians for referrals and that they hence add to the "medical arms race" of competition by increasing levels of medically unnecessary services[14]; some also argue that specialty hospitals "cherry pick" services that are profitable or patients who are healthy from general hospitals.[34] In contrast, people in favor of hospital specialization argue that specialty hospitals are "focused factories" that offer more efficient and specialized care to patients based on either direct or spillover effects, as hospital specialization often leads to more efficient treatment than in general hospitals[35] and spurs neighboring general hospitals to become more responsive and up-to-date in their practices. These benefits of hospital specialization are described by Herzlinger, and described in a way that is analogous to Skinner's concept of the "focused factory" in the general economic realm.[36]

The direct benefits of hospital specialization can originate from at least three factors. First, specialized hospitals may better exploit economies of scale by consolidating volume that would have otherwise been allocated to many different facilities given the substantial amount of fixed investment needed to provide services such as cardiac surgery or orthopedic procedures. (However, Dranove and Shanley[37] indicate that hospital systems do not appear to have lower costs than other similar “pseudo systems,” and Dranove[37] provides evidence of only relatively small scale economies in “non-revenue producing cost centers.”) Second, specialty hospitals may benefit from volume aggregations that can either reduce cost or improve the quality of care. In fact, according to the GAO, specialized hospitals may treat more patients in their field of specialization because of their focused missions, despite their lack of beds compared to general hospitals.[34] The large body of evidence of the positive association between volume and outcome for many surgical procedures leads to the suggestion that such advantages may be best obtained by single-specialty facilities that will be successful in aggregating volume within a market.[38-40] Third, specialty hospitals may provide more powerful incentives to achieve efficiency and other cost or quality improvements by permitting physicians to share in the efficiency gains through ownership. Apart from these direct effects, general hospitals in the same market as specialized hospitals may also be forced to become more efficient to avert the risk of declining prices or reduced market share. However, even so, critics of specialty hospitals argue that the features noted above make specialty hospitals on the whole more efficient and better able to attract the most profitable patient types than general hospitals.

If reimbursement systems such as Medicare’s prospective payment system (PPS) are unable to fully compensate hospitals for treating patients with severe illness that are more expensive to treat, seeking healthier patients can naturally be a profitable business strategy. Of course, by law, no hospital is allowed to turn away acutely ill patients. However, critics note that specialty hospitals are likely to be able to shape their patient populations more easily than general hospitals, as they have more discretion over the provided services and can hence promote services that healthier patients more highly value. In this way, patient selection within a certain illness can significantly affect hospital profits.

4. Hospital Specialization and Performance

Several studies have analyzed the relationship between hospital specialization and hospital performance to date. These have used either the Information Theory Index,[1,12,20,24,41,42] the inner Herfindahl Index,[12,41-43] number of distinct DRGs treated,[12,41] or the Gini coefficient[44] as measures of specialization.

In the Korean context, in 2015, Kim et al.[12] examined data from 1,810 Korea hospitals for the year 2011 and calculated specialization based on the Information Theory Index and the inner Herfindahl Index using diagnosis-related groups as diagnosis categories. Also in 2015, Kwak et al.[41] examined data from 1,513 Korea hospitals for the year 2009, 1,586 Korea hospitals for the year 2010 and 1,666 Korea hospitals for the year 2011 and calculated specialization based on the Information Theory Index, inner Herfindahl Index, and number of distinct DRGs treated using diagnosis-related groups as diagnosis categories. In 2013, Moon et al.[43] examined data from 170 Korea hospitals for the year 2009, and calculated specialization based on the inner Herfindahl Index. In 2010, Lee et al.[12] examined data from 61 Korea hospitals for the year 2003-2005 and calculated specialization based on the Information Theory Index, inner Herfindahl Index, and number of distinct DRGs treated, using diagnosis-related groups as diagnosis categories. In some studies from other countries, in 1999, Linna and Häkkinen[24] examined data from 95 Finnish hospitals for the year 1994 and calculated specialization based on the Information Theory Index, using diagnosis-related groups as diagnosis categories. (Lee et al.[1] examined 106 Korean hospitals in 2004 following the same approach.) Another long-term panel study, using data from more than 1,500 German hospitals for the years 1995 through 2006, was conducted by Herwartz and Strumann.[4] They used specialization based on Information Theory Index and applied hospital department as diagnosis categories.

In an Italian study, Daidone and D'Amico[4] based their study on data from 108 Italian hospitals for the years 2000 through 2005 and used the Major Diagnostic Categories classification scheme to form diagnosis categories for their Gini-based specialization measure. Atella et al.[45] also used Gini-based specialization, dividing it into quartiles, but their paper makes no mention of which diagnosis categories were used. Their study was based on data from a panel of 1,233 Italian hospitals for the years 1999 through 2007.

The designs of others among these previous studies differ considerably from the ones presented above. Two of the studies cited above used long-term panel data, covering 8[45] and 11 years[20] respectively, from samples of more than 1,200 hospitals. In contrast, the other studies analyzed samples of about 100 hospitals. Whereas Linna and Häkkinen,[26] Kwak et al.,[41] Kim et al.,[42] and Lee et al.[12,25] used cross-sectional data, Daidone and D'Amico[44] had panel data covering six years. Moreover, the studies used either data envelopment analysis[20,24,25] or a stochastic frontier approach based on different functions, and Daidone and D'Amico,[4] Herwartz and Strumann,[20] and Atella et al.[21] investigated technical efficiency, whereas Linna and Häkkinen[26] investigated cost efficiency, Kwak et al.[41] investigated cost per case, Kim et al.[42] investigated profitability, efficiency, productivity and quality of care, Moon et al.[43] investigated LOS, and Barro et al.[33] investigated mortality rate.

Whereas Linna and Häkkinen[26], Lee et al.,[25] and Daidone and D'Amico[4] found specialization to be positively associated with efficiency, Atella et al.[21] found the relationship to be negative, Herwartz and Strumann[20] found that the relationship changed over time, Lee et al.[12] found that the specialization score by specialization index changed over time, Kwak et al.[41] found the relationship to increase cost per case, and Kim et al.[42]

found the inner Herfindahal-Hirschman index to improve the income and adjusted number of patients per specialist through the efficient utilization of human resources, but the Information Theory Index to improve the hospital utilization ratio, income per bed, and adjusted number of patients per bed. Two previous studies[46,47] about hospital specialization and cost efficiency indicated that the observed 30.6% rise in specialization for the period 1991–2000 was associated with a 8.2% decline in unit cost per admission, while the observed 26.9% rise in specialization for the period 1983–1990 was associated with a 6.9% decline in unit cost per admission. Moon et al.[43] found that inner Herfindahl Index was not statistically significant in explaining variation of average LOS. Finally, Barro et al.[33] showed that patients admitted to a specialty hospital are much more likely to receive an intensive cardiac procedure, resulting in substantially better health outcomes. In addition, they are much less likely to die within one year (14% versus 23.9%) and have lower rates of cardiac complications.

IV. Study Methods

1. Study Population and Design

This study used Korean National Health Insurance Service–Cohort Sample Data (NHIS-CSD) from 2002 to 2013, released by the Korean National Health Insurance Service (KNHIS). Initial NHIS-CSD cohort members (n = 1,025,340) were established by stratified random sampling using a systematic sampling method to generate a representative sample of the 46,605,433 Korean residents recorded in 2002. The cohort members were followed up to 2013. The data comprise a nationally representative random sample of 1,025,340 individuals, approximately 2.2% of the entire population in 2002. If a cohort member was censored due to death or emigration, a new member was recruited from among newborns for the same calendar year.

The present study utilized data on healthcare utilization claims, including patient specifications such as hospital cost (per case and per diem), LOS, and mortality, as well as hospital specifications. In order to analyze the relationship between hospital specialization and hospital costs (per case and per diem), this study used the International Classification of Diseases, Tenth Revision (ICD-10) codes of all inpatients within each hospital by year (see Appendix A1, Appendix A2).

This study developed a separate individual database for each hospital, including the calendar years and transposing claim data into a longitudinal design for repeated measurement. The hospitals allowed us to study the associations between hospital specialization and outcomes during a 12-year follow-up.

To measure IHI, ITI, CMS, ICMS, and modified CMS for all hospitals, there were no exclusion criteria in these regards. The exception was for lumbar spine disease specialization, where our exclusion criterion was one or more case of lumbar spine disease per year per hospital. This study also calculated anesthesia cost, procedure or surgery cost, injection cost, examination cost, medication cost, admission cost and total cost (Figure 1) per visit.

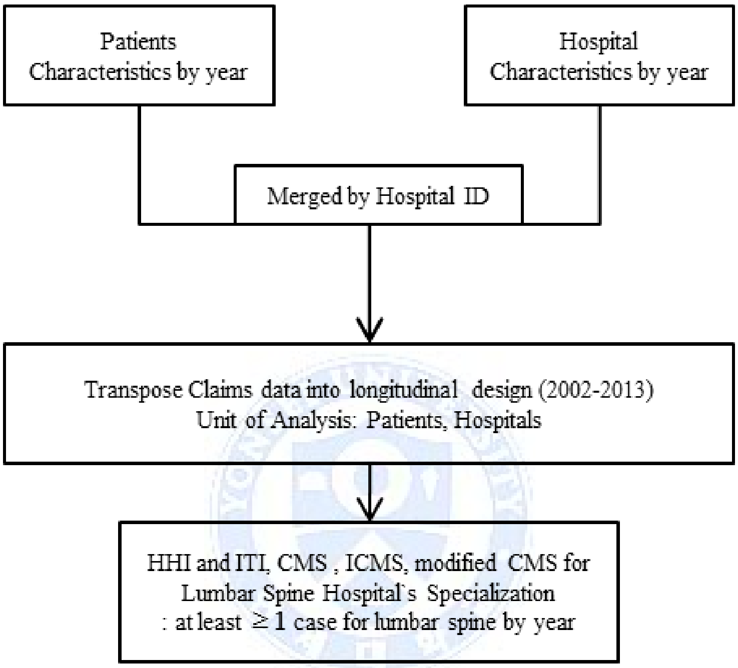

Figure 1. Flow Chart of Subject Selection

Based on the conceptual framework of the study design (Figure 2), this study ought to find factors associated with hospital costs (per case and per diem), LOS, and mortality of all lumbar spine disease inpatients within the sampled hospitals.

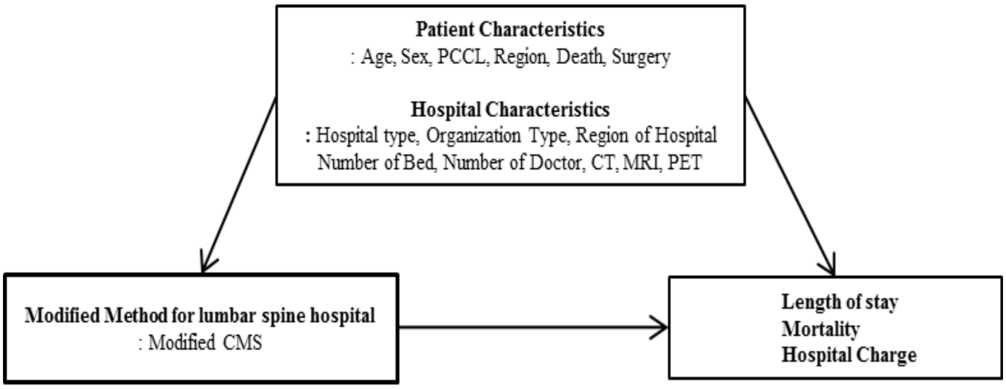

Figure 2. Conceptual Framework of Study Design

2. Study methods for achieving the study objectives

In this study, the nationwide cohort sample data over 12 years used for this study was investigated in three parts, to meet the study objectives.

First, we identified the distribution of hospital specialization scores over time per each hospital specialization measure to examine whether the level of hospital specialization consistently increased or decreased over time. We also identified limitations of hospital specialization measures such as IHI, ITI, CMS, and ICMS for measuring specialization in specific diseases (such as lumbar spine disease).

Second, given that IHI, ITI, CMS, and ICMS tend to return decreasing hospital specialization scores when measuring specialization in a specific disease, we developed and implemented modified CMS. To verify its validity in the Korean health care environment, we examined hospital distribution by proportion and absolute number of lumbar spine patients. In addition, we conducted cluster analysis to identify groups of individuals or objects that were similar to each other but different from individuals in other groups, and compared goodness-of-fit by clusters through a generalized estimating equation (GEE) regression model accounting for correlation among individuals within each hospital on LOS, total cost per case, and total cost per diem.

Finally, to verify the validity of modified CMS, we investigated the association between modified CMS and LOS, total cost per case, and total cost per diem through a GEE regression model accounting for correlation among individuals within each hospital.

3. Independent Variables

This study incorporated individual- and hospital-level variables including age, sex, residential region, surgery, death, hospital type, organization type, region of hospital, number of beds, number of doctors, presence of CT, presence of MRI, presence of PET, and a year dummy.

Lists of individual-level and hospital-level variables are in Table 3. The age variable is categorized into three groups: ≤29, 30–39, 40–49, 50–59, 60–69, and ≥70. The sex variable is categorized into two groups: male and female. Residential region is categorized into three groups: metropolitan (Seoul), urban (Daejeon, Daegu, Busan, Incheon, Kwangju, or Ulsan), and rural (everywhere else). Surgery and death variables are categorized into two groups: yes and no.

The hospital type variable is categorized into three groups: tertiary hospital, general hospital, and hospital. The organization type variable was categorized into three groups: public, corporate, and private. The region of hospital variable was categorized into three groups: metropolitan (Seoul), urban (Daejeon, Daegu, Busan, Incheon, Kwangju, or Ulsan) and rural (everywhere else). The number of beds variable was categorized into nine groups: ≤199, 200–299, 300–399, 400–499, 500–599, 600–699, 700–799, 800–899, and ≥900. The number of doctors variable was categorized into seven groups: ≤49, 50–99, 100–149, 150–199, 200–249, 250–299, and ≥300. In addition, presence of CT, presence of MRI, and presence of PET were categorized into two groups: yes or no. Finally, a year dummy variable was included in our analysis. We measured hospital specialization using the main independent variables: IHI, ITI, CMS, ICMS, and modified CMS, as continuous variables (Table 1).

Table 1. Definition of independent variables

Variables		Definition
Individual Level	**Age**	(1) ≤29 (2) 30-39 (3) 40-49 (4) 50-59 (5) 60-69 (6) ≥70
	Sex	(1) Male (2) Female
	Region	(1) Metropolitan (2) Urban (3) Rural
	Surgery	(1) Yes (2) No
	Death	(1) Yes (2) No
Hospital Level	**Hospital Type**	(1) Tertiary Hospital (2) General Hospital (3) Hospital
	Organization Type	(1) Public (2) Corporate (3) Private
	Region of Hospital	(1) Metropolitan (2) Urban (3) Rural
	Number of Bed	(1) ≤199 (2) 200-299 (3) 300-399 (4) 400-499 (5) 500-599 (6) 600-699 (7) 700-799 (8) 800-899 (9) ≥900
	Number of Doctor	(1) ≤49 (2) 50-99 (3) 100-149 (4) 150-199 (5) 200-249 (6) 250-299 (7) ≥300
	Presence of CT	(1) Yes (2) No
	Presence of MRI	(1) Yea (2) No
	Presence of Pet	(1) Yea (2) No
	Year	(1) 2002 (2) 2003 (3) 2004 (4) 2005 (6) 2006 (7) 2007 (8) 2008 (9) 2009 (10) 2010 (11) 2011 (12) 2012 (13) 2013
	IHI	Continuous
	ITI	Continuous
	CMS	Continuous
	ICMS	Continuous
	Modified CMS	Continuous

4. Dependent Variables

To investigate our hypothesis, this study used LOS, mortality, total cost per case (anesthesia cost per case, procedure or surgery cost per case, injection cost per case, examination cost per case, admission cost per case, and medication cost per case), and total cost per diem (anesthesia cost per diem, procedure or surgery cost per diem, injection cost per diem, examination cost per diem, admission cost per diem, and medication cost per diem) as dependent variables. (See Table 2.)

Table 2. Lists of Dependent Variables

Dependent variables
LOS
Mortality
Total cost per case
Anesthesia cost per case
Procedure or surgery cost per case
Injection cost per case
Examination cost per case
Admission cost per case
Medication cost per case
Total cost per diem
Anesthesia cost per diem
Procedure or surgery cost per diem
Injection cost per diem
Examination cost per diem
Admission cost per diem
Medication cost per diem

In Korea, the fees for services (FFS) catalogue is negotiated by the government, care providers, and other stakeholders every year. This study discounted hospital charges for all inpatients on the basis of catalogue for the year 2002 using each year`s negotiated FFS catalogue.

5. Statistical analysis

In this study, the units of analysis are each individual and each hospital. Thus, this study employed analysis of variance (ANOVA); cluster analysis, to identify groups of individuals or objects that are similar to each other but different from individuals in other groups; and generalized estimating equation (GEE) regression model accounting for correlation among individuals within each hospitals to investigate whether general characteristics and hospital specialization had a relationship with mortality, LOS, or hospital costs (anesthesia cost, procedure or surgery cost, injection cost, examination cost, medication cost, admission cost). In GEE, *proc genmod* was used, with *link identity*, *distribution normal.*

This terminology draws on a common specification of the GEE regression model,

$$Y_{it} = \beta_0 + \beta_1 \times Hospital\ specialization_{it} + \beta_2 \times X_{it} + e_{it}$$

where Y_{it} is the dependent variable (i.e., anesthesia cost, procedure or surgery cost, injection cost, examination cost, medication cost, admission cost and total cost) during a time period *t* for unit *i*.

Y_{it} is the dependent variables

β_0 is the intercept

$Hospital\ specialization_{it}$ is the interesting variable

X_{it} is the covariates

e_{it} is the error term

This study adjusted for age, sex, PCCL, residential region, death, surgery, hospital type, organization type, region of hospital, number of bed, number of doctor, presence of CT, presence of MRI, presence of PET and year. SAS 9.4 (SAS Institute, Cary, NC) was used to estimate all calculation and our hypothesis. All statistical significance tests were two-tailed and rejected null hypothesis of no difference if p-values were less that 0.05 or equivalent.

6. Ethics Statement

This study was approved by an institutional review board of Graduate school of Public Health, Yonsei University. [IRB Number: 2-1040939-AB-N-01-2015-415]

V. Results

1. Distribution of hospital specialization

(1) Changes of hospital specialization score by hospital specialization index over time

Table 3 shows whether level of hospital specialization consistently increases or decreases over time. As can be seen, IHI (2002: 0.013 [SD: 0.055] → 2013: 0.038 [0.107]), ITI (2002: 0.204 [SD: 0.503] → 2013: 0.454 [0.887]), CMS (2002: 0.021 [SD: 0.050] → 2013: 0.042 [0.109]), modified CMS (2002: 0.182 [SD: 0.254] → 2013: 0.240 [0.240]) showed a slight increase over time. However, ICMS showed little difference over time.

Table 3. Changes of hospital specialization by hospital specialization over time

	IHI		ITI		CMS		ICMS		Modified CMS	
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
2002	0.013	0.055	0.204	0.503	0.021	0.050	0.001	0.013	0.182	0.254
2003	0.032	0.128	0.335	0.877	0.032	0.117	0.011	0.090	0.175	0.300
2004	0.030	0.115	0.336	0.840	0.029	0.103	0.008	0.077	0.152	0.280
2005	0.026	0.103	0.308	0.789	0.030	0.105	0.006	0.070	0.159	0.306
2006	0.026	0.102	0.323	0.802	0.034	0.114	0.007	0.075	0.174	0.329
2007	0.028	0.100	0.338	0.794	0.031	0.104	0.005	0.062	0.162	0.318
2008	0.034	0.109	0.403	0.859	0.034	0.109	0.005	0.053	0.174	0.345
2009	0.036	0.118	0.415	0.879	0.039	0.114	0.008	0.074	0.187	0.335
2010	0.039	0.115	0.437	0.882	0.038	0.110	0.006	0.064	0.188	0.343
2011	0.037	0.105	0.428	0.847	0.043	0.108	0.004	0.048	0.242	0.367
2012	0.039	0.110	0.453	0.864	0.041	0.096	0.005	0.058	0.226	0.336
2013	0.038	0.107	0.454	0.887	0.042	0.109	0.006	0.050	0.240	0.334

(2) Hospital specialization trend according to number of bed and hospital type

Figure 3–4 shows the trend of the mean values of lumbar spine disease by hospital, obtained using hospital specialization indexes according to the number of beds and hospital type. HHI, ITI, CMS, and ICMS for lumbar spine disease hospitals show a decreasing trend, that is, the larger the scale of the hospital, the less the specialization, is mentioned above. However, to measure hospital specialization in a specific disease, we took a log transformation to the denominator of CMS to reduce between-hospital variation of number of medical categories, because the maximum disease category is up to three to extract a specific disease (e.g. lumbar spine disease) regardless of the scale of the hospital in terms of hospital type or number of beds.

As can be seen, a U-shaped trend of modified CMS exists from small to large hospitals, associated with higher hospital specialization.

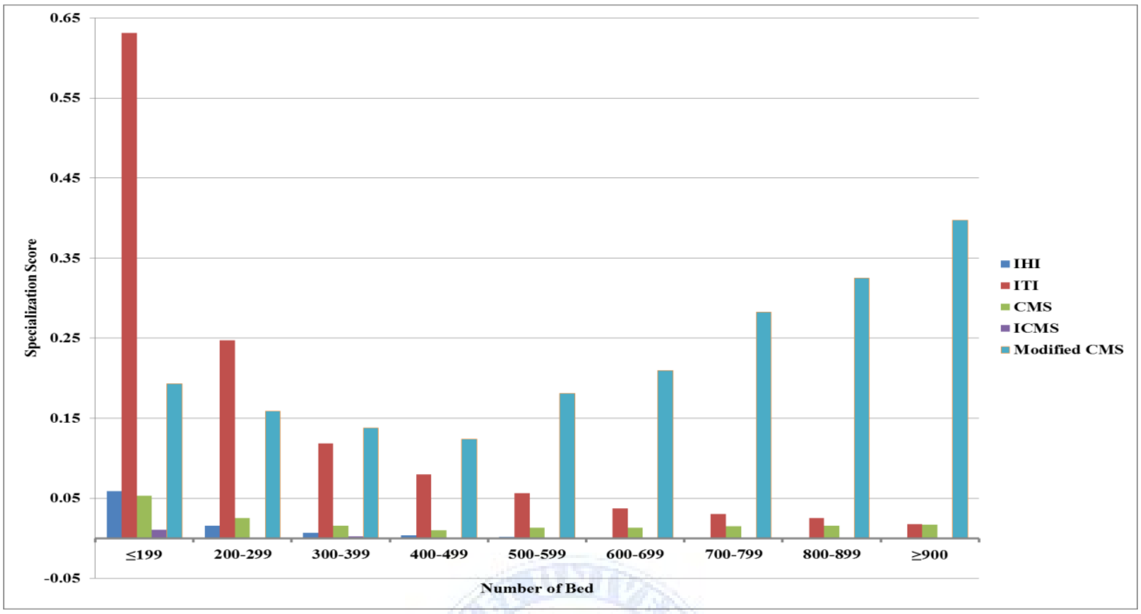

Figure 3. Hospital specialization trend by number of beds

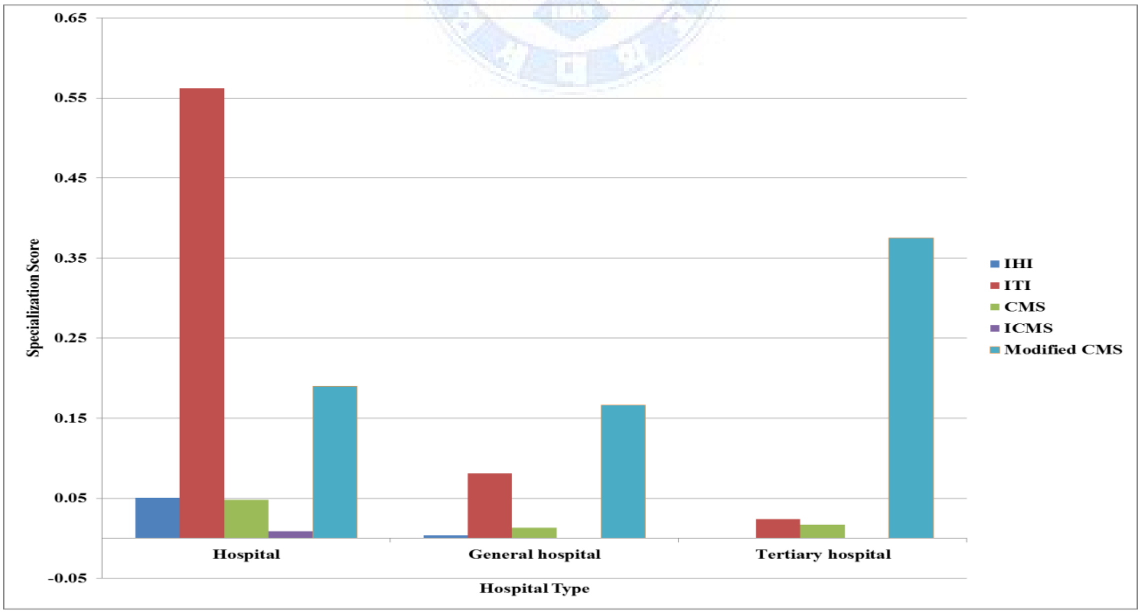

Figure 4. Hospital specialization trend by hospital type

(3) Results of correlation analysis between hospital specialization index

Table 4 presents the correlation analyses of all hospital specialization methods using the Pearson correlation coefficients. IHI was significantly and positively correlated with ITI, while CMS had a significant correlation with ICMS and modified CMS (Table 4).

Table 4. Correlation analysis by hospital specialization

	IHI	ITI	CMS	ICMS	Modified CMS
IHI	1				
ITI	0.984 <.0001	1			
CMS	0.397 <.0001	0.394 <.0001	1		
ICMS	0.406 <.0001	0.404 <.0001	0.984 <.0001	1	
Modified CMS	0.369 <.0001	0.366 <.0001	0.976 <.0001	0.964 <.0001	1

2. Hospital distribution by proportion and absolute number of lumbar spine disease patients

(1) Number of hospital by proportion and absolute number of lumbar spine disease patients

Table 5 shows number of hospitals by proportion of total patients who were lumbar spine disease patients. Of 8,339 hospitals, tertiary hospitals account for 482, general hospitals for 2,418, and hospitals for 5,439. Of 8,339 hospitals, the number with ≥80% total patients being treated for lumbar spine disease is 200 (2.4%); that with ≥70% proportion, 289 (3.5%); that with ≥60% proportion, 406 (4.9%); and that with <60%, 7,933 (95.1%).

Table 5. Hospital distribution by proportion

	Proportion of lumbar spine disease patients for total patients								
	≥80%		≥70%		≥60%		<60%		Sum
	N	%	N	%	N	%	N	%	
Tertiary hospital	-	-	-	-	-	-	482	100.000	482
General hospital	8	0.003	9	0.004	9	0.004	2,409	0.996	2,418
Hospital	192	0.035	280	0.051	397	0.073	5,042	0.927	5,439
Total	200	0.024	289	0.035	406	0.049	7,933	0.951	8,339

Table 6 shows hospital distribution by absolute number of total patients who are lumbar spine disease patients. Of 8,339 hospitals, the number with <20 lumbar spine disease patients is 7,774 (93.2%), that with 20–39 is 347 (4.2%), that with 40-59 is 109 (1.3%), and that with ≥60 is 109 (1.3%).

Table 6. Hospital distribution by absolute number

	Absolute number of lumbar spine disease patients								
	<20		20-39		40-59		≥60		Sum
	N	%	N	%	N	%	N	%	
Tertiary hospital	405	0.840	60	0.124	13	0.027	4	0.008	482
General hospital	2,345	0.970	58	0.024	6	0.002	9	0.004	2,418
Hospital	5,024	0.924	229	0.042	90	0.017	96	0.018	5,440
Total	7,774	0.932	347	0.042	109	0.013	109	0.013	8,339

(2) Number of hospital by proportion and absolute number of lumbar spine disease patients

Figure 5 shows hospital distributions by absolute number and proportion of total patients who are lumbar spine disease patients, and Table 7 examines the correlation between the proportion and the absolute number by hospital type as well as overall. The correlation result between proportion and absolute number of lumbar spine disease patients for total hospitals were 0.512 (p: <.0001), while the result for tertiary hospitals was 0.511 (p: <.0001); for general hospitals, 0.811 (p: <.0001); and for hospitals, 0.574 (p: <.0001) (Table 7).

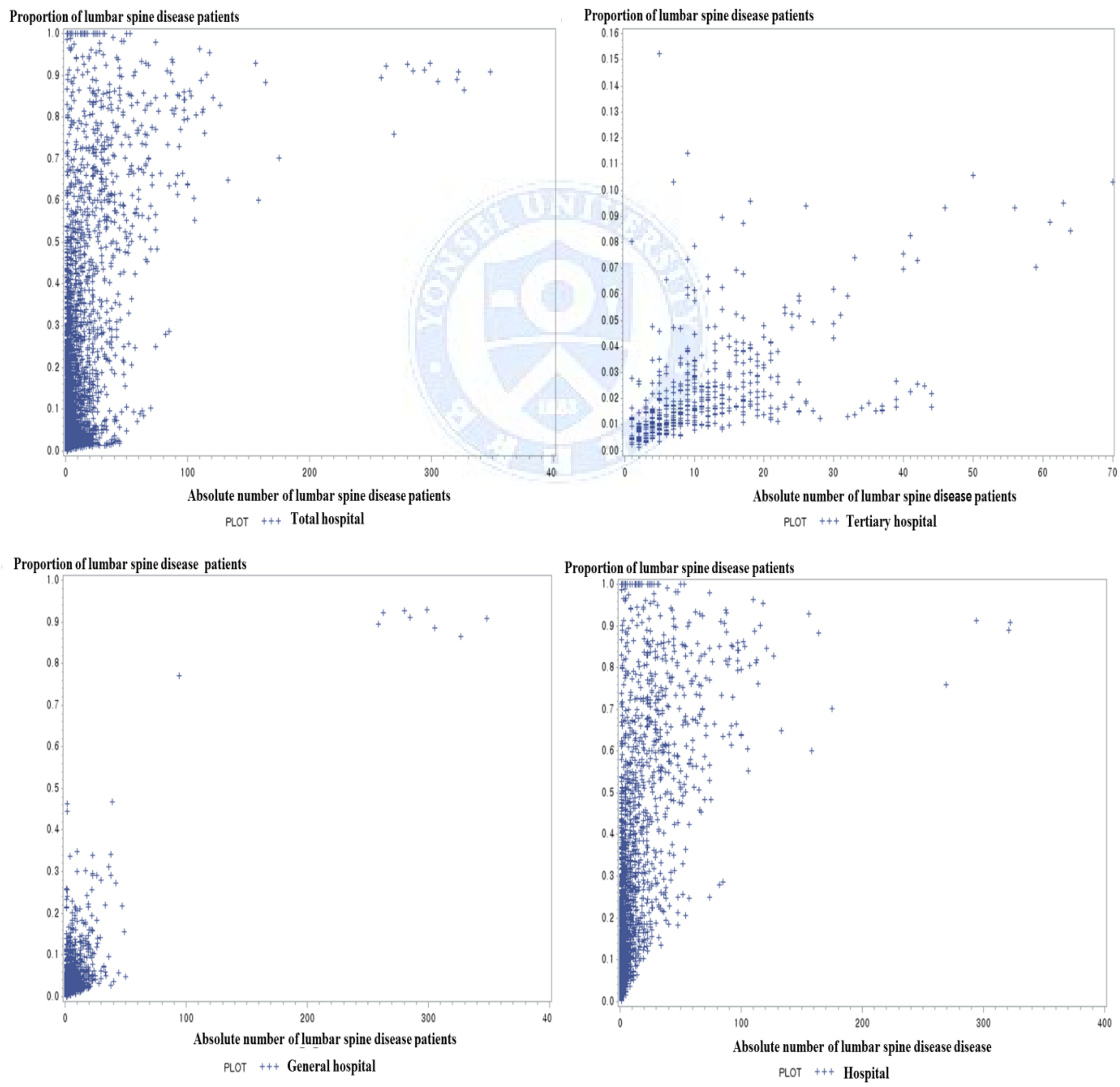

Figure 5. Proportion and absolute number by hospital type

Table 7. Correlation between proportion and absolute number by hospital type

Hospital type	Total	Tertiary hospital	General hospital	Hospital
Correlation	0.512	0.511	0.811	0.574
	<.0001	<.0001	<.0001	<.0001

(3) Each hospital specialization by absolute number and proportion of lumbar spine disease patients

Figure 6 shows modified CMS by absolute number of lumbar spine disease patients according to hospital specialization index among total hospitals (see Appendix B1). Figure 7 shows hospital specialization by proportion of total patients who are lumbar spine disease patients according to hospital specialization index among total hospitals (see Appendix B2). Figure 8 shows hospital specialization by absolute number of lumbar spine disease patients according to hospital specialization index among general hospitals (see Appendix B3). Figure 9 shows hospital specialization by proportion of total patients who are lumbar spine disease patients according to hospital specialization index among general hospitals (see Appendix B4). Figure 10 shows hospital specialization by absolute number of lumbar spine disease patients according to hospital specialization index among hospitals (see Appendix B5). Figure 11 show hospital specialization by proportion of total patients who are lumbar spine disease patients according to hospital specialization index among hospitals (see Appendix B6).

Table 8 shows the results of correlation analysis between hospital specialization index and absolute hospital volume of lumbar spine disease patients by hospital type using the Pearson correlation coefficient. IHI (0.892, p: <.0001) and ITI (0.991, p: <.0001) show higher correlation for proportion of total patients who are lumbar spine disease patients than CMS (0.815, p: <.0001), ICMS (0.373, p: <.0001) or modified CMS (0.701, p: <.0001) among total hospitals. However, modified CMS (0.611, p: <.0001) shows a higher correlation for absolute number of lumbar spine disease patients than HHI (0.378, p: <.0001), ITI (0.489, p: <.0001), CMS (0.449, p: <.0001), or ICMS (0.025, p: <.0001) among total hospitals.

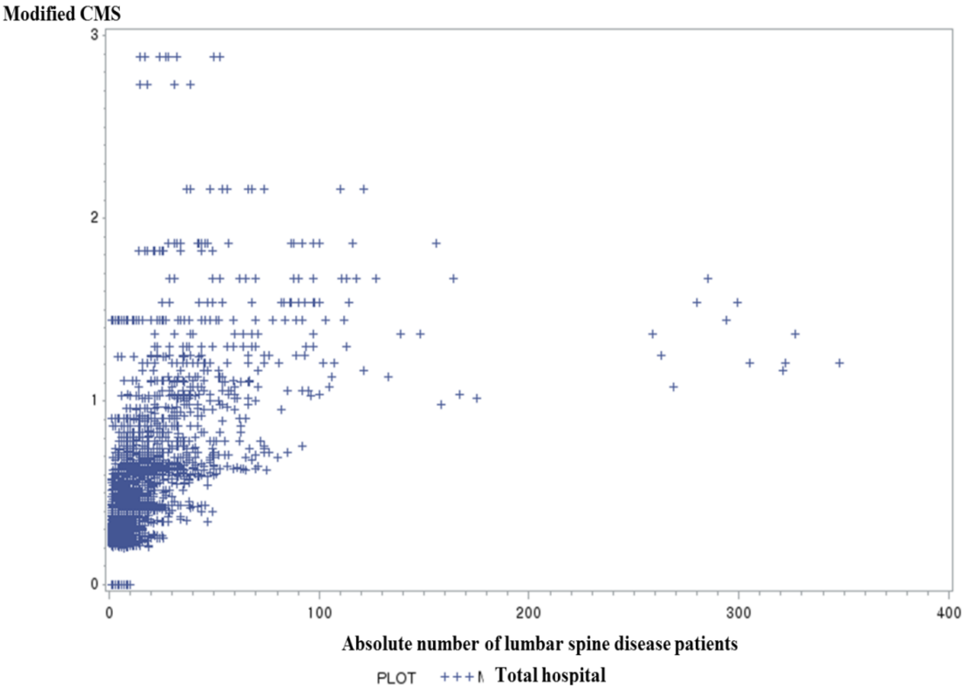

Figure 6. Modified CMS and absolute number among total hospital

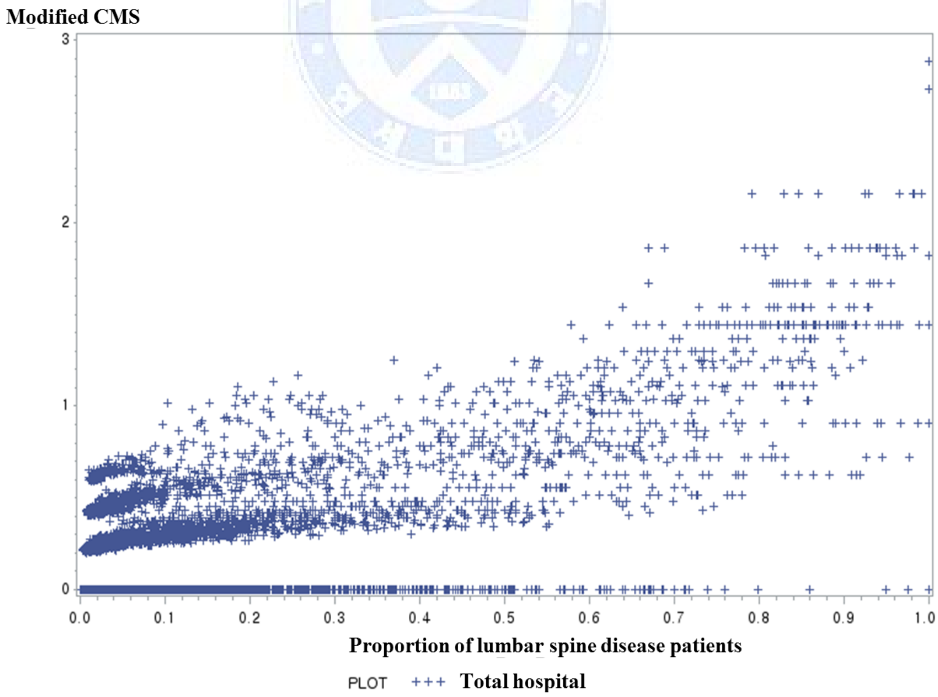

Figure 7. Modified CMS and proportion among total hospital

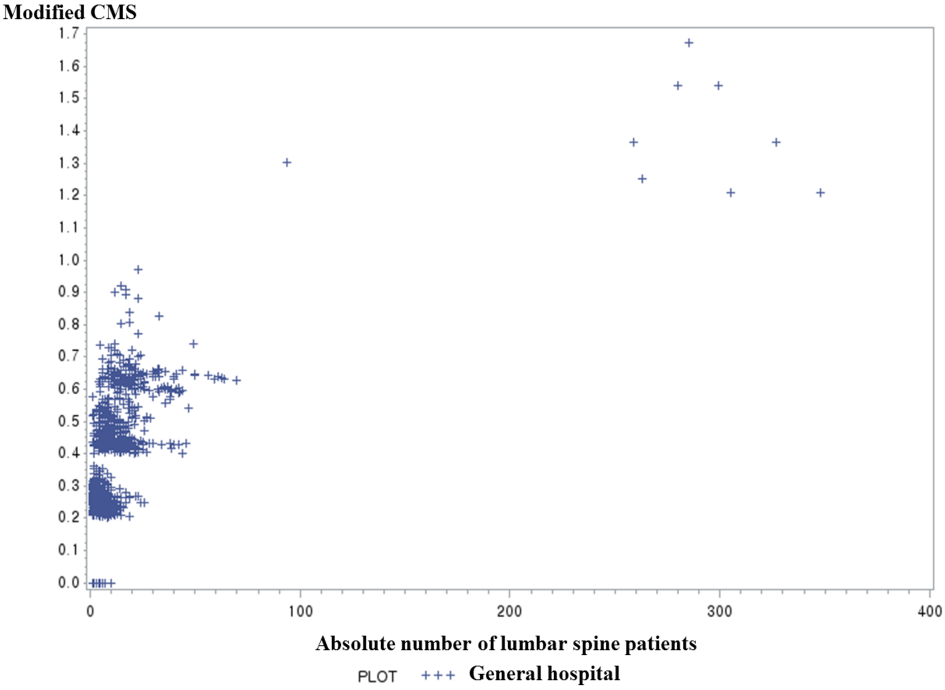

Figure 8. Modified CMS and absolute number among general hospital

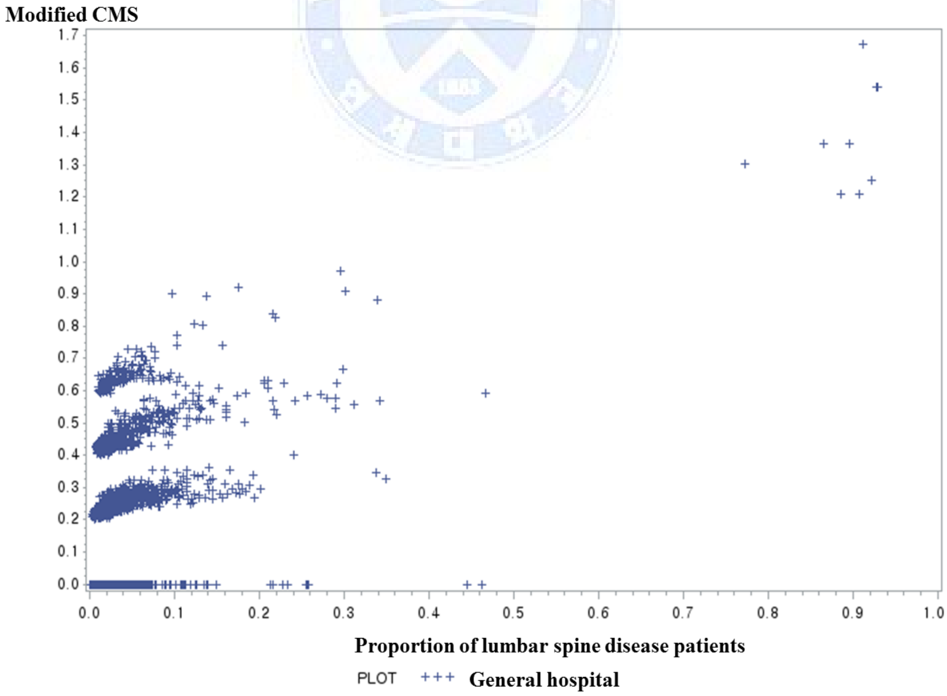

Figure 9. Modified CMS and proportion among general hospital

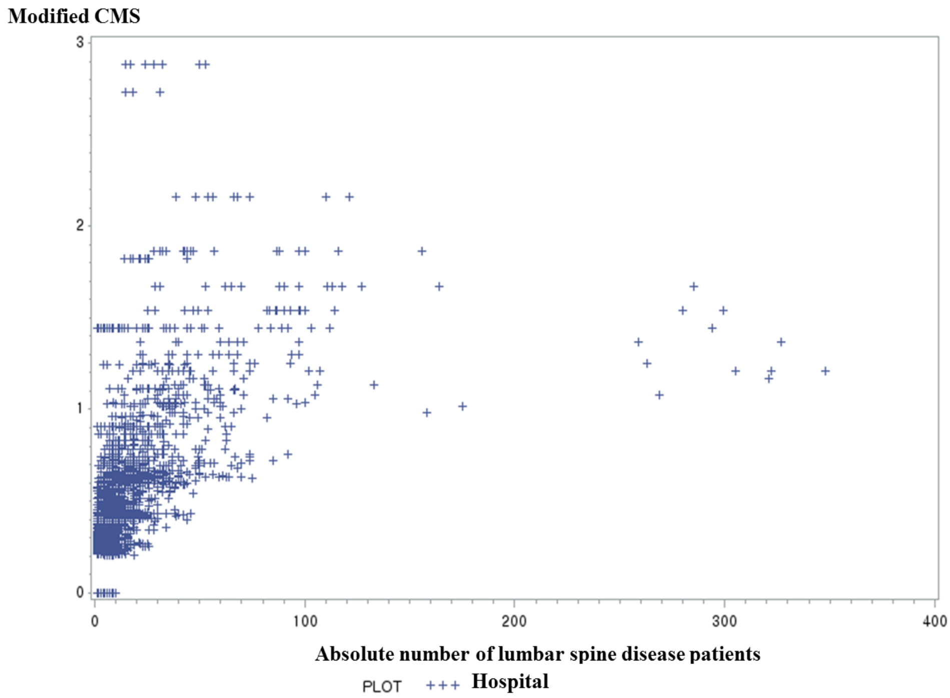

Figure 10. Modified CMS and absolute number among hospital

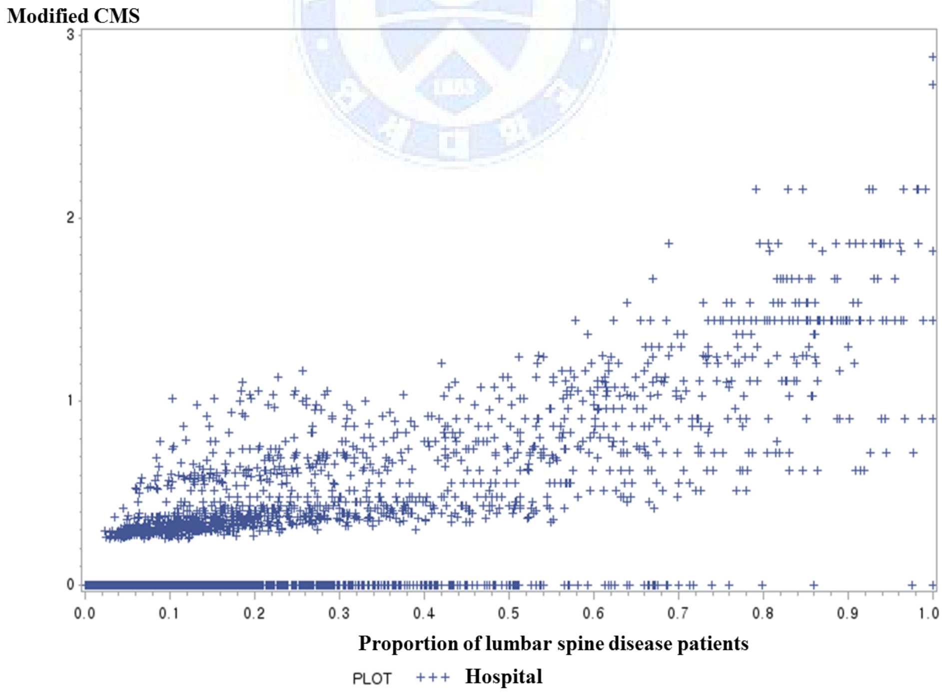

Figure 11. Modified CMS and proportion among hospital

Table 8. Correlation between hospital specialization and absolute number

IHI		ITI		CMS		ICMS		Modified CMS	
Proportion*	Absolute**	Proportion*	Absolute**	Proportion*	Absolute **	Proportion *	Absolute **	Proportion*	Absolute**
Total									
0.892	0.378	0.991	0.489	0.815	0.449	0.373	0.025	0.701	0.611
<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	0.045	<.0001	<.0001
General hospital									
0.900	0.858	0.982	0.802	0.828	0.795	0.718	0.835	0.437	0.543
<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
Hospital									
0.889	0.388	0.990	0.530	0.820	0.485	0.386	0.022	0.782	0.649
<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	0.205	<.0001	<.0001

Proportion*: Proportion of lumbar spine patients
Absolute**: Absolute number of lumbar spine patients

(4) Subgroup analysis by proportion of lumbar spine disease patients for total patients

Figure 12 shows hospital specialization by absolute number of lumbar spine disease patients among hospitals where ≥80% of total patients are lumbar spine disease patients, according to hospital specialization index (see Appendix C1). Figure 13 shows hospital specialization by absolute number of lumbar spine disease patients among hospitals with ≥70% lumbar spine disease patients (see Appendix C2). Figure 14 show hospital specialization by absolute number of lumbar spine disease patients among hospitals with ≥60% lumbar spine disease patients (see Appendix C3).

Table 9 shows the results of correlation analysis between hospital specialization index and absolute hospital volume of lumbar spine disease patients by proportion of total patients who are lumbar spine disease patients, using the Pearson correlation coefficient. As can be seen, although IHI, ITI, CMS, and ICMS have negative associations with absolute number of lumbar spine disease patients, modified CMS has a positive association with it. These trends increase as the proportion of lumbar spine disease patients moves from ≥80% (0.187, p: 0.011) to ≥60% (0.281, p: <.0001) of lumbar spine disease patients (Table 9).

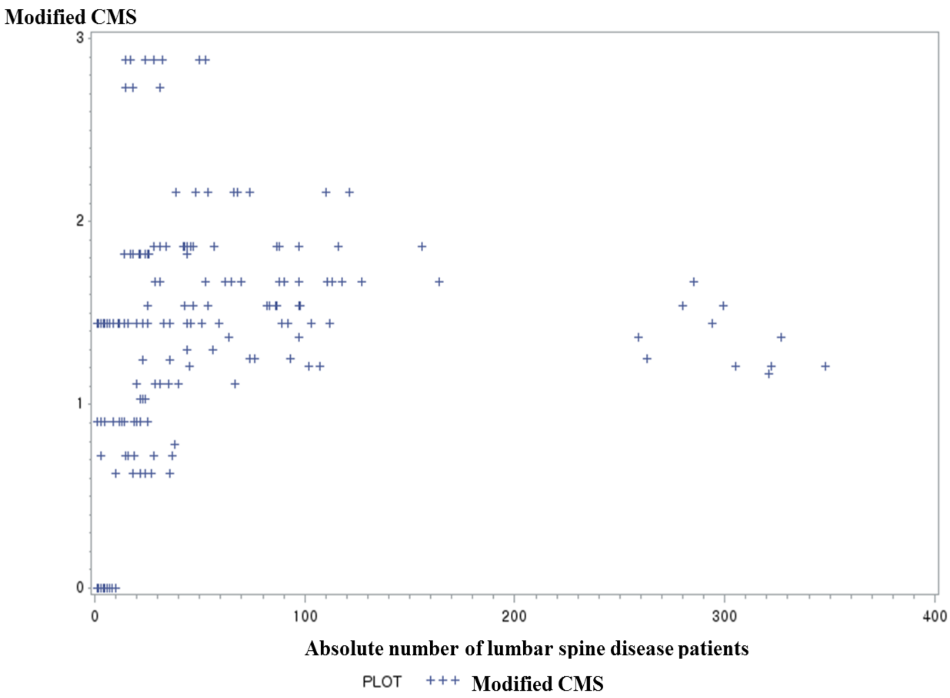

Figure 12. Modified CMS and absolute number (≥80% hospitals)

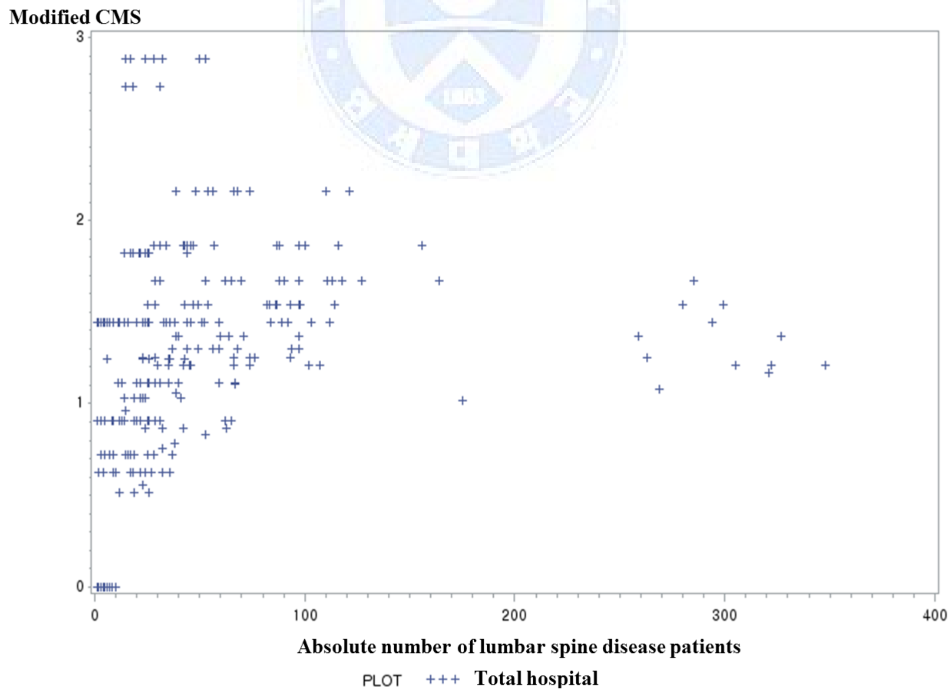

Figure 13. Modified CMS and absolute number (≥70% hospitals)

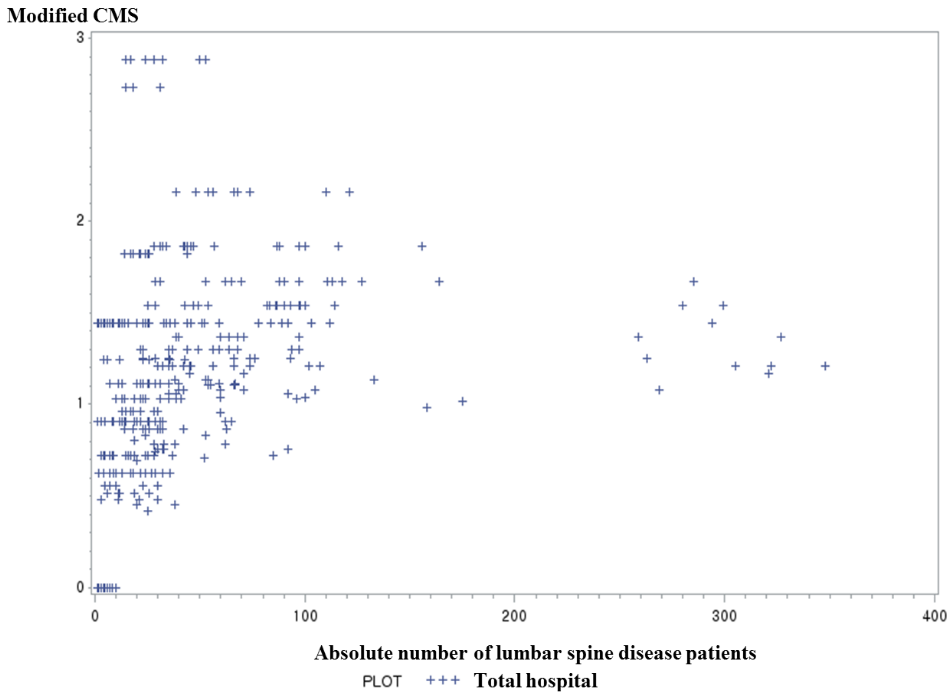

Figure 14. Modified CMS and absolute number (≥60% hospitals)

Table 9. Correlation between hospital specialization and absolute number by proportion

	HHI	ITI	CMS	ICMS	Modified CMS
≥80% of lumbar spine disease patients	-0.420	-0.391	-0.236	-0.335	0.187
	<.0001	<.0001	0.001	<.0001	0.011
≥70% of lumbar spine disease patients	-0.344	-0.230	-0.123	-0.277	0.232
	<.0001	0.000	0.042	<.0001	0.000
≥60% of lumbar spine disease patients	-0.246	-0.092	-0.033	-0.227	0.281
	<.0001	0.072	0.523	<.0001	<.0001

(5) Hospital distribution by proportion and absolute number of lumbar spine disease patients through cluster analysis

Following cluster analysis, Figure 15 shows hospital distributions for proportion of total patients who are lumbar spine disease patients and for absolute number of lumbar spine disease patients. Figure 16 shows proportion of total patients who are lumbar spine disease patients and absolute number of lumbar spine disease patients among hospitals with ≥80% lumbar spine disease patients. Figure 17 shows proportion of total patients who are lumbar spine disease patients and absolute number of lumbar spine disease patients among hospitals with ≥70% lumbar spine disease patients. Figure 18 shows proportion of total patients who are lumbar spine disease patients and absolute number of lumbar spine disease patients among hospitals with ≥60% lumbar spine disease patients.

Table 10 shows the results of correlation between proportion of total patients who are lumbar spine disease patients and absolute number of lumbar spine disease patients using the Pearson correlation coefficients over the three clusters (that is, according to proportion [total, ≥80%, ≥70%, and ≥60%] of lumbar spine disease patients). As you can see, within cluster 1, proportion of total patients who are lumbar spine disease patients has a positive association with absolute number of lumbar spine disease patients (0.338, p: <.0001); the same is true within cluster 2 (0.166, p: <.0001) and within cluster 3 (0.240, p: <.0001) (Table 10).

Table 11 shows the results for goodness-of-fit gained through GEE analysis between each hospital specialization and LOS; total cost per case; and total costs per diem (for detailed table, see Appendix B1-B3). Overall, modified CMS and cluster 3, which showed greater proportions and absolute numbers of lumbar patients, had excellent model fit (Table 11) (see Appendix D1-D3).

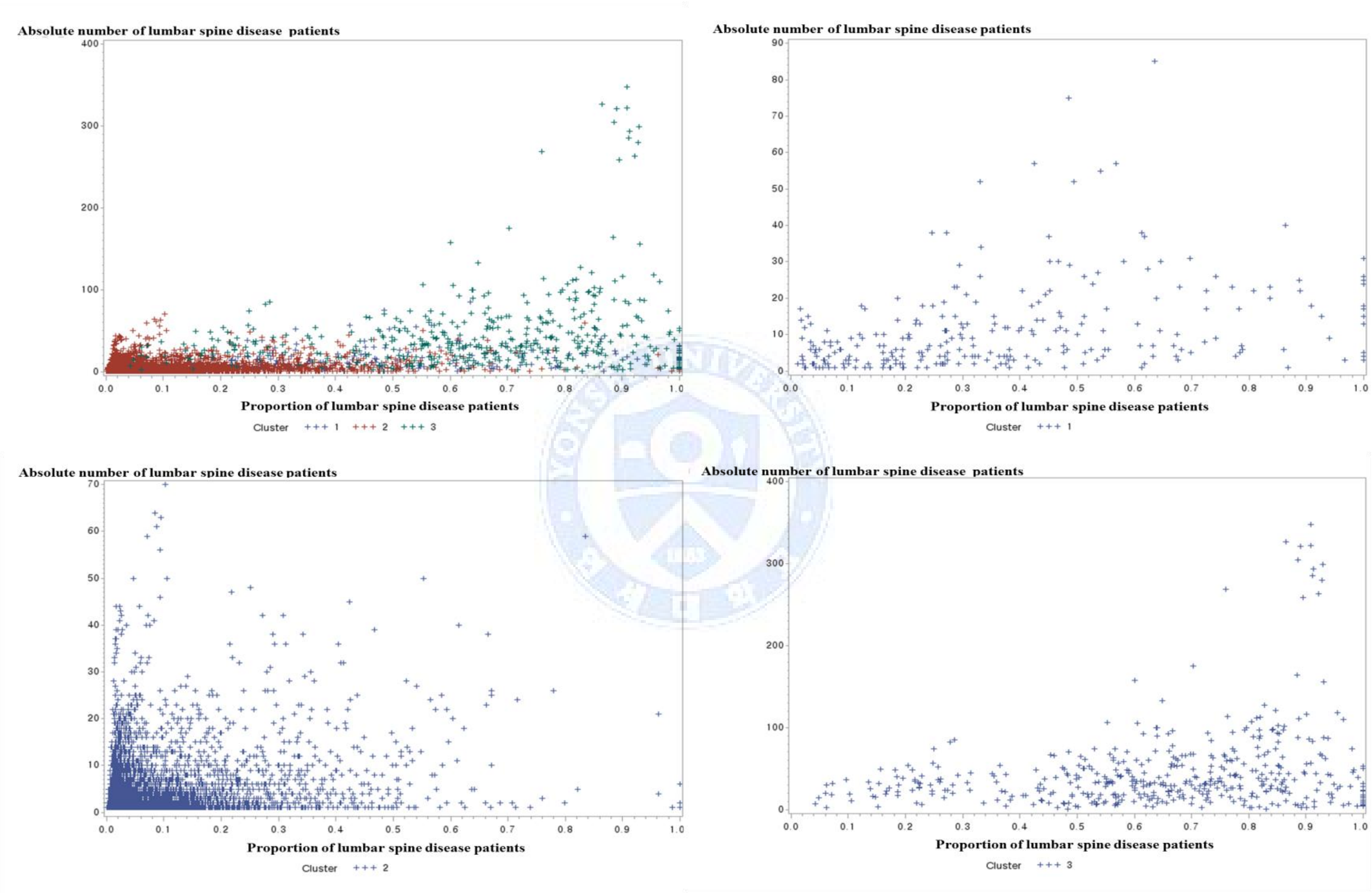

Figure 15. Proportion and absolute number by cluster (Total hospitals)

Figure 16. Proportion and absolute number by cluster (≥80% hospitals)

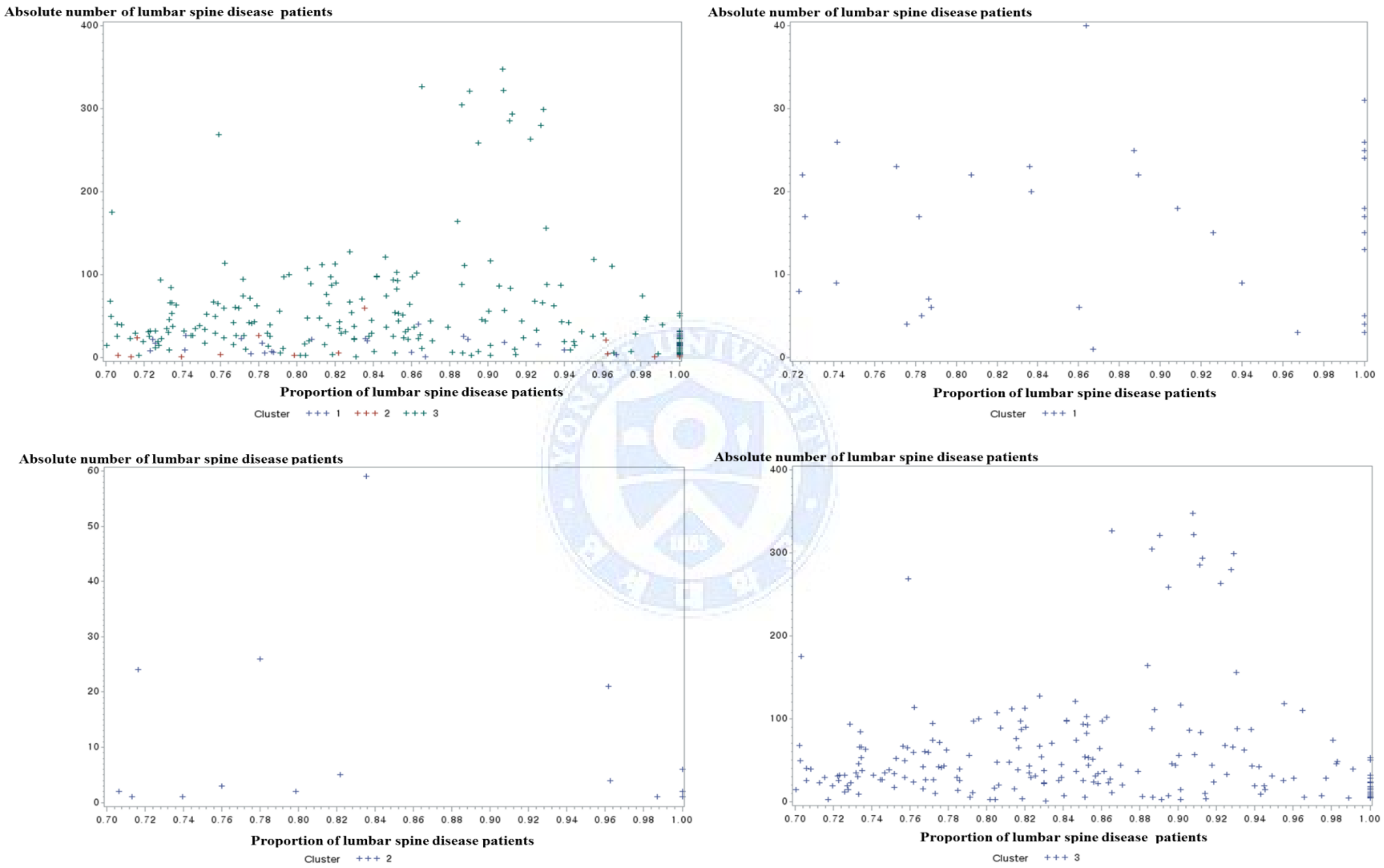

Figure 17. Proportion and absolute number by cluster (≥70% hospitals)

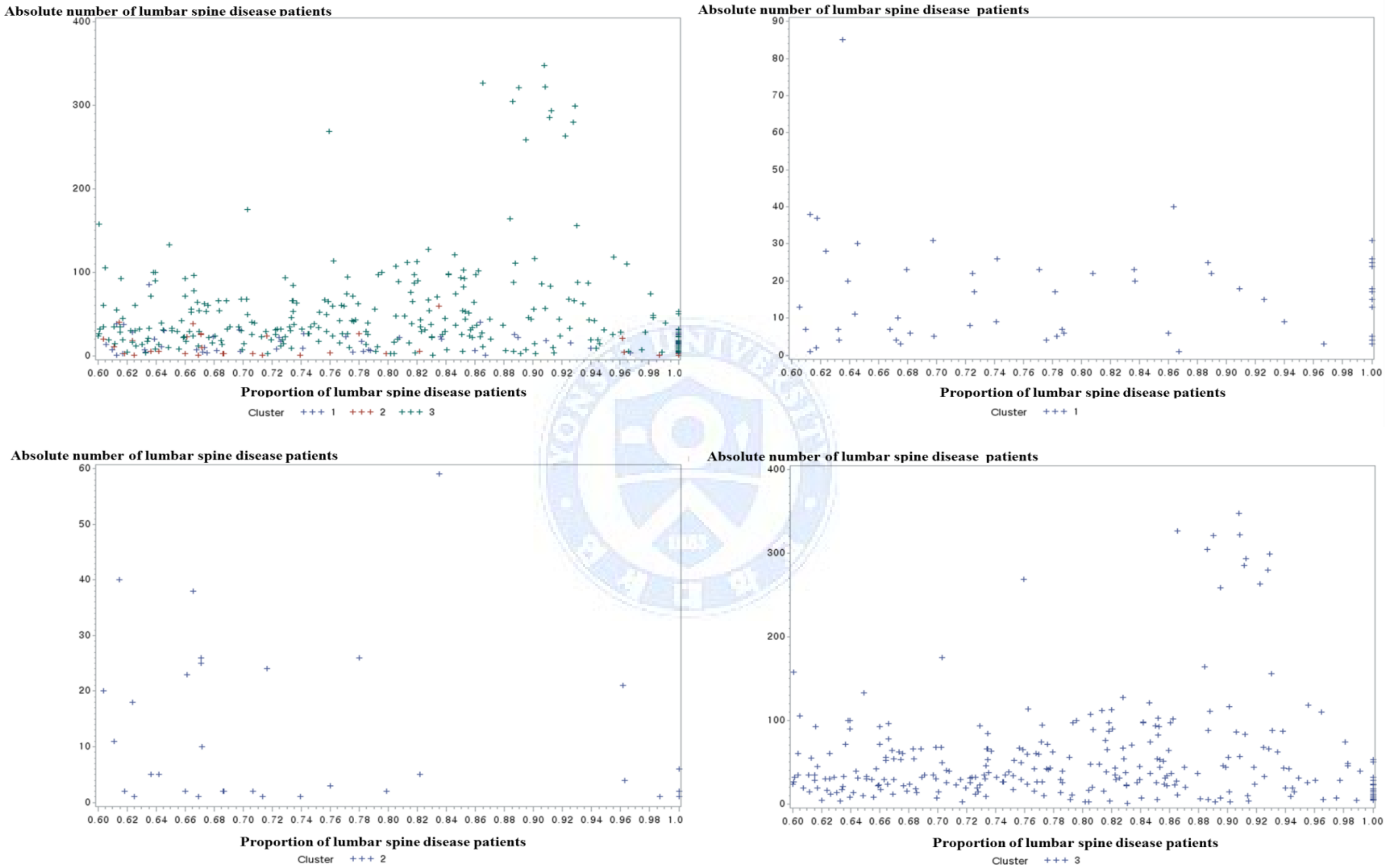

Figure 18. Proportion and absolute number by cluster (≥60% hospitals)

Table 10. Correlation between proportion and absolute number

	Total	≥80% of lumbar spine disease patients	≥70% of lumbar spine disease patients	≥60% of lumbar spine disease patients
Cluster 1	0.338	-0.172	0.047	-0.060
	<.0001	0.391	<.0001	0.652
Cluster 2	0.166	-0.675	-0.290	-0.323
	<.0001	0.004	0.179	0.042
Cluster 3	0.240	-0.101	0.049	0.121
	<.0001	0.230	0.476	0.040

Table 11. Comparison of goodness of fit through GEE analysis by hospital specialization

	Length of stay			Total cost per case			Total cost per diem		
	Cluster 1	Cluster 2	Cluster 3	Cluster 1	Cluster 2	Cluster 3	Cluster 1	Cluster 2	Cluster 3
Total patients									
IHI	22,348.8	12,193.5	22,438.2	22,461.3	12,472.0	22,755.3	22,015.5	12,053.1	22,293.3
ITI	22,348.1	12,193.8	22,438.2	22,461.5	12,474.2	22,755.6	22,014.8	12,054.3	22,293.7
CMS	22,346.3	12,193.4	22,437.8	22,461.5	12,472.6	22,756.5	22,016.5	12,051.3	22,294.3
ICMS	22,342.8	12,193.1	22,436.6	22,460.6	12,471.6	22,753.5	22,026.2	12,050.3	22,292.0
Modified CMS	22,345.6	12,192.7	22,437.3	22,462.8	12,474.3	22,755.4	22,014.8	12,050.7	22,291.6
Surgery patients									
IHI	8,427.7	2,758.6	10,582.3	8,512.7	2,921.9	10,704.5	8,402.4	3,009.0	10,578.3
ITI	8,426.7	2,759.0	10,582.0	8,512.4	2,923.5	10,703.4	8,402.4	3,011.0	10,577.6
CMS	8,424.9	2,758.3	10,581.5	8,512.0	2,921.9	10,703.4	8,402.4	3,009.0	10,579.5
ICMS	8,421.2	2,758.2	10,580.6	8,510.2	2,921.6	10,704.0	8,401.4	3,008.8	10,578.0
Modified CMS	8,424.1	2,759.5	10,580.2	8,513.0	2,922.7	10,702.7	8,402.9	3,008.0	10,578.7
non-Surgery patients									
IHI	13,960.8	9,505.0	11,853.2	13,974.4	9,504.2	11,871.9	13,689.7	9,372.2	11,771.6
ITI	13,960.6	9,505.2	11,853.1	13,974.5	9,504.7	11,872.2	13,688.8	9,373.6	11,772.3
CMS	13,959.9	9,505.0	11,852.8	13,974.7	9,504.7	11,872.2	13,690.8	9,369.9	11,771.6
ICMS	13,958.6	9,504.9	11,853.7	13,975.5	9,504.0	11,871.6	13,700.3	9,368.2	11,770.8
Modified CMS	13,957.8	9,505.6	11,852.6	13,974.8	9,503.7	11,872.0	13,688.6	9,371.4	11,770.4

***Adjusted for all variables**

3. Modified CMS and LOS, mortality, total cost per case and total cost per diem

(1) Results of General Characteristics of all variables

Table 12 shows results for general characteristics of all variables by surgery and mortality, and Table 13 shows results for general characteristics of all variables by LOS, total cost per case, and total cost per diem.

According to Table 12, of the 56,622 total cases included in our analysis, there were 21,317 surgery cases (37.7%) and 283 mortality cases (0.5%). Average LOS of total cases was 11.564 days (SD: 10.139), average total costs per case of total cases were 2,941,444 (SD: 3,876,058), and average total costs per diem of total cases was 275,882 (SD: 483,928). LOS of tertiary hospitals was 12.340 (SD: 10.258), LOS of general hospitals was 12.965 (SD: 12.214), and LOS of hospitals was 10.863 (SD: 9.083). Total cost per case of tertiary hospitals was 4,073,357 (SD: 4,827,482), total cost per case of general hospitals was 3,084,961 (SD: 4,351,142), and total cost per case of hospitals was 2,675,627 (SD: 3,409,682). Total cost per diem of tertiary hospitals was 365,897 (SD: 821,742), total cost per diem of general hospitals was 277,903 (SD: 513,120), and total cost per diem of hospitals was 258,568 (SD: 374,123).

LOS of hospitals with ≤199 beds was 10.470 days (SD: 8.901), LOS of hospitals with 200–299 beds was 11.507 days (SD: 11.036), LOS of hospitals with 300-399 beds was 14.210 days (SD: 11.155), and LOS of hospitals with ≥900 beds was 12.005 days (SD: 9.283).

Total cost per case of hospitals with ≤199 beds was 2,515,714 won (SD: 3,197,653), that of hospitals with 200–299 beds was 3,009,791 won (SD: 3,699,586), that of hospitals with 300-399 beds was 2,885,936 won (SD: 5,506,214), and that of hospitals with ≥900 beds was 3,894,471 won (SD: 4,652,814). Total cost per diem of hospitals with ≤199 beds was 247,930 won (SD: 349,336), that of hospitals with 200-299 beds was 310,114 won (SD: 493,649), that of hospitals with 300-399 beds was 207,580 won (SD: 407,818), and that of hospitals with ≥900 beds was 353,465 won (SD: 807,264) (Table 13).

Table 12. General characteristics of all variables for analysis (surgery, mortality)

	Total		Surgery					Mortality				
			Yes		No		P-value	Yes		No		P-value
	N	%	N	%	N	%		N	%	N	%	
Hospital level												
Type							<.0001					<.0001
Tertiary Hospital	6,593	11.6	2,639	40.0	3,954	60.0		55	0.8	6,538	99.2	
General Hospital	14,257	25.2	4,954	34.8	9,303	65.3		78	0.6	14,179	99.5	
Hospital	35,772	63.2	13,724	38.4	22,048	61.6		150	0.4	35,622	99.6	
Organization Type							<.0001					<.0001
Public	725	1.3	176	24.3	549	75.7		14	1.9	711	98.1	
Corporate	21,369	37.7	7,619	35.7	13,750	64.4		161	0.8	21,208	99.3	
Private	34,528	61.0	13,522	39.2	21,006	60.8		108	0.3	34,420	99.7	
Region							<.0001					0.0002
Metropolitan	18,800	33.2	8,030	42.7	10,770	57.3		64	0.3	18,736	99.7	
Urban	17,022	30.1	6,870	40.4	10,152	59.6		87	0.5	16,935	99.5	
Rural	20,800	36.7	6,417	30.9	14,383	69.2		132	0.6	20,668	99.4	
Bed							<.0001					<.0001
≤199	26,886	47.5	10,186	37.9	16,700	62.1		103	0.4	26,783	99.6	
200-299	12,986	22.9	5,260	40.5	7,726	59.5		56	0.4	12,930	99.6	
300-399	2,895	5.1	774	26.7	2,121	73.3		26	0.9	2,869	99.1	
400-499	1,319	2.3	331	25.1	988	74.9		11	0.8	1,308	99.2	
500-599	1,696	3.0	541	31.9	1,155	68.1		10	0.6	1,686	99.4	
600-699	1,387	2.5	462	33.3	925	66.7		8	0.6	1,379	99.4	
700-799	1,198	2.1	450	37.6	748	62.4		4	0.3	1,194	99.7	
800-899	1,424	2.5	609	42.8	815	57.2		9	0.6	1,415	99.4	
≥900	6,831	12.1	2,704	39.6	4,127	60.4						
Doctor							0.002					<.0001
≤49	42,870	75.7	15,952	37.2	26,918	62.8		194	0.5	42,676	99.6	
50-99	3,025	5.3	1,144	37.8	1,881	62.2		12	0.4	3,013	99.6	
100-149	1,347	2.4	505	37.5	842	62.5		10	0.7	1,337	99.3	
150-199	1,444	2.6	575	39.8	869	60.2		2	0.1	1,442	99.9	
200-249	1,116	2.0	426	38.2	690	61.8		3	0.3	1,113	99.7	
250-299	1,490	2.6	577	38.7	913	61.3		15	1.0	1,475	99.0	
≥300	5,330	9.4	2,138	40.1	3,192	59.9		47	0.9	5,283	99.1	
CT							0.707					0.4946
No	2,907	5.1	1,104	38.0	1,803	62.0		12	0.4	2,895	99.6	
Yes	53,715	94.9	20,213	37.6	33,502	62.4		271	0.5	53,444	99.5	
MRI							<.0001					<.0001
No	3,283	5.8	443	13.5	2,840	86.5		45	1.4	3,238	98.6	
Yes	53,339	94.2	20,874	39.1	32,465	60.9		238	0.5	53,101	99.6	
PET							<.0001					0.0007
No	43,956	77.6	16,307	37.1	27,649	62.9		196	0.5	43,760	99.6	
Yes	12,666	22.4	5,010	39.6	7,656	60.5		87	0.7	12,579	99.3	
Individual level												
PCCL							<.0001					<.0001
0	39,143	69.1	13,595	34.7	25,548	65.3		108	0.3	39,035	99.7	
1	11,424	20.2	5,208	45.6	6,216	54.4		66	0.6	11,358	99.4	
2	5,261	9.3	2,233	42.4	3,028	57.6		73	1.4	5,188	98.6	
3	794	1.4	281	35.4	513	64.6		36	4.5	758	95.5	
Sex							0.810					0.2458
Male	26,666	47.1	10,053	37.7	16,613	62.3		143	0.5	26,523	99.5	
Female	29,956	52.9	11,264	37.6	18,692	62.4		140	0.5	29,816	99.5	
Age							<.0001					<.0001
≤29	4,316	7.6	1,266	29.3	3,050	70.7		1	0.0	4,315	100.0	
30-39	7,309	12.9	2,227	30.5	5,082	69.5		2	0.0	7,307	100.0	
40-49	9,993	17.7	3,440	34.4	6,553	65.6		6	0.1	9,987	99.9	
50-59	12,712	22.5	4,926	38.8	7,786	61.3		27	0.2	12,685	99.8	
60-69	12,114	21.4	5,433	44.9	6,681	55.2		59	0.5	12,055	99.5	
≥70	10,178	18.0	4,025	39.6	6,153	60.5		188	1.9	9,990	98.2	
Region							0.553					0.0017
Metropolitan	9,962	17.6	3,791	38.1	6,171	62.0		30	0.3	9,932	99.7	
Urban	13,339	23.6	4,983	37.4	8,356	62.6		60	0.5	13,279	99.6	
Rural	33,321	58.9	12,543	37.6	20,778	62.4		193	0.6	33,128	99.4	
Death							<.0001					
Yes	283	0.5	59	20.9	224	79.2		283	100.0	-	-	
No	56,339	99.5	21,258	37.7	35,081	62.3		-	-	56,339	100.0	
Year							<.0001					0.111
2002	1,453	2.6	589	40.5	864	59.5		-	-	1,453	100.0	
2003	1,964	3.5	810	41.2	1,154	58.8		9	0.5	1,955	99.5	
2004	2,372	4.2	992	41.8	1,380	58.2		10	0.4	2,362	99.6	
2005	3,276	5.8	1,437	43.9	1,839	56.1		14	0.4	3,262	99.6	
2006	3,523	6.2	1,485	42.2	2,038	57.9		26	0.7	3,497	99.3	
2007	4,148	7.3	1,776	42.8	2,372	57.2		23	0.6	4,125	99.5	
2008	4,818	8.5	1,904	39.5	2,914	60.5		22	0.5	4,796	99.5	
2009	5,482	9.7	2,185	39.9	3,297	60.1		33	0.6	5,449	99.4	
2010	6,204	11.0	2,388	38.5	3,816	61.5		35	0.6	6,169	99.4	
2011	7,259	12.8	2,553	35.2	4,706	64.8		37	0.5	7,222	99.5	
2012	8,133	14.4	2,689	33.1	5,444	66.9		44	0.5	8,089	99.5	
2013	7,990	14.1	2,509	31.4	5,481	68.6		30	0.4	7,960	99.6	
Total	56,622	100.0	21,317	37.7	35,305	62.4		283	0.5	56,339	99.5	

Table 13. General characteristics of all variables (LOS, total cost)

(Unit: days, won)

	Length of Stay			Total Cost per case			Total Cost per diem		
	Mean	**SD**	**P-value**	**Mean**	**SD**	**P-value**	**Mean**	**SD**	**P-value**
Hospital level									
Type			<.0001			<.0001			0.0004
Tertiary Hospital	12.340	10.258		4,073,357	4,827,482		365,897	821,742	
General Hospital	12.965	12.214		3,084,961	4,351,142		277,903	513,120	
Hospital	10.863	9.083		2,675,627	3,409,682		258,568	374,123	
Organization Type			<.0001			0.2109			<.0001
Public	16.039	15.975		3,226,527	5,510,078		216,969	493,928	
Corporate	12.772	10.539		3,369,909	4,475,030		288,624	583,690	
Private	10.722	9.616		2,670,286	3,379,137		269,304	410,536	
Region			<.0001			<.0001			<.0001
Metropolitan	9.715	9.017		3,109,011	3,847,805		341,082	518,786	
Urban	13.258	10.889		3,271,190	4,042,084		266,172	521,540	
Rural	11.849	10.189		2,520,137	3,722,206		224,726	406,041	
Bed			<.0001			<.0001			<.0001
≤199	10.470	8.901		2,515,714	3,197,653		247,930	349,336	
200-299	11.507	11.036		3,009,791	3,699,586		310,114	493,649	
300-399	14.210	11.155		2,885,936	5,506,214		207,580	407,818	
400-499	13.324	11.529		2,670,602	3,557,473		226,261	426,559	
500-599	15.242	11.927		3,469,678	4,187,909		272,043	742,036	
600-699	14.610	14.011		3,821,565	5,230,944		296,492	519,921	
700-799	13.573	10.702		3,896,925	5,895,635		268,919	280,308	
800-899	14.580	12.535		3,857,991	3,879,661		296,764	345,553	
≥900	12.005	9.283		3,894,471	4,652,814		353,465	807,264	
Doctor			<.0001			<.0001			<.0001
≤49	11.272	9.798		2,692,606	3,556,071		256,485	386,024	
50-99	11.728	14.138		2,965,897	3,954,385		351,910	664,742	
100-149	14.520	11.693		3,802,614	4,607,958		281,665	741,486	
150-199	13.755	11.325		3,713,833	5,007,180		278,344	384,235	
200-249	13.258	10.068		3,706,323	5,108,694		288,947	342,877	
250-299	12.736	9.136		3,534,084	3,982,408		299,960	592,477	
≥300	11.796	9.356		4,176,295	4,938,677		378,279	851,768	
CT			0.2753			0.0005			<.0001
No	10.073	7.327		2,392,039	2,901,786		232,260	287,055	
Yes	11.645	10.263		2,971,177	3,919,712		278,250	492,258	
MRI			<.0001			<.0001			<.0001
No	13.030	10.030		1,773,690	2,570,092		162,979	389,843	
Yes	11.474	10.139		3,013,319	3,931,032		282,815	488,269	
PET			<.0001			0.0043			<.0001
No	11.342	10.230		2,690,128	3,570,272		259,464	424,430	
Yes	12.334	9.781		3,813,610	4,684,820		333,393	647,519	
Individual level									
PCCL			<.0001			<.0001			<.0001
0	9.918	8.513		2,366,234	3,124,208		262,627	482,602	
1	14.381	11.015		4,084,060	4,426,943		306,522	354,896	
2	16.822	14.123		4,706,630	5,982,440		315,587	685,841	
3	17.355	15.086		3,162,558	3,921,545		224,798	508,493	
Sex			<.0001			0.3495			<.0001
Male	10.637	9.713		2,591,159	3,671,664		267,903	441,874	
Female	12.390	10.436		3,253,258	4,023,822		282,977	518,372	
Age			<.0001			<.0001			<.0001
≤29	8.308	7.240		1,369,066	1,794,441		220,628	378,160	
30-39	8.592	7.160		1,508,280	1,743,870		210,589	337,449	
40-49	10.302	9.628		2,116,664	2,616,372		233,283	506,684	
50-59	11.763	9.974		3,090,064	3,654,968		284,153	448,818	
60-69	13.366	10.336		4,043,988	4,731,798		332,486	549,210	
≥70	13.926	12.191		3,949,300	4,929,566		310,534	535,593	
Region			0.0731			0.0021			0.0003
Metropolitan	9.990	10.100		2,935,998	4,537,192		306,564	441,434	
Urban	12.692	10.225		3,022,640	3,902,546		257,350	550,549	
Rural	11.583	10.055		2,910,568	3,643,598		274,136	466,803	
Death			<.0001			<.0001			<.0001
Yes	12.781	11.222		2,817,350	3,848,167		296,535	668,160	
No	11.558	10.133		2,942,068	3,876,222		275,779	482,838	
Year			<.0001			<.0001			0.7751
2002	12.424	9.530		3,311,334	3,952,227		313,640	559,053	
2003	12.823	11.648		2,856,296	3,288,238		264,448	330,068	
2004	12.637	14.212		2,727,633	3,266,189		291,371	430,242	
2005	12.533	12.838		3,232,273	4,000,586		340,784	562,475	
2006	12.789	11.187		3,124,003	3,665,188		282,838	383,053	
2007	12.397	10.011		3,236,505	3,875,078		292,414	408,736	
2008	12.531	10.207		3,097,829	3,814,858		277,667	510,071	
2009	12.665	11.377		3,321,143	4,521,166		276,274	434,815	
2010	11.740	9.008		3,165,761	4,665,550		266,456	320,008	
2011	10.630	9.001		2,683,059	3,378,635		256,839	430,593	
2012	10.334	8.483		2,708,282	3,833,982		271,484	660,299	
2013	10.037	8.616		2,548,756	3,456,698		256,028	507,837	
Total	11.564	10.139		2,941,444	3,876,058		275,882	483,928	

(2) Results of adjusted effects of GEE analysis for association between Modified CMS and LOS, mortality, total cost per case and total cost per diem

Table 14 shows the results for the adjusted effect of the association between modified CMS and LOS among total patients, including both surgery and non-surgery lumbar spine disease patients, adjusting for hospital type, organization type, region of hospital, number of beds, number of doctors, presence of CT, presence of MRI, presence of PET, PCCL, age, sex, residential region, surgery, death, and year. Inpatients admitted with lumbar spine disease at hospitals with higher modified CMS had a shorter LOS (Estimate: -1.700, 95% CI: -1.886 – -1.514, p: <.0001). LOS was 1.072 days longer (95% CI: 0.548 – 1.595, p: <.0001) in tertiary hospital compared with hospitals (Table 14). Table 15 shows the results for the adjusted effect of association between modified CMS and mortality among total patients, including both surgery and non-surgery lumbar spine disease patients, adjusting for hospital type, organization type, region of hospital, number of beds, number of doctors, presence of CT, presence of MRI, presence of PET, PCCL, age, sex, residential region, surgery, and year. Inpatients admitted with lumbar spine disease at hospitals with higher modified CMS had a lower mortality rate (OR: 0.635, 95% CI: 0.521 – 0.775, p: <.0001): 2.122 times higher (95% CI: 1.389 – 3.243, p: 0.001) in public hospitals and 1.371 times higher (95% CI: 1.110 – 1.694, p: 0.003) in corporate hospitals as compared with private hospitals (Table 15). Table 16 shows the results for the adjusted effect of association between modified CMS and total cost per case among total patients, including both surgery and non-surgery lumbar spine disease patients, adjusting for hospital type, organization type, region of hospital, number of beds, number of doctors, presence of CT, presence of MRI, presence of PET, PCCL, age, sex, residential region, surgery, death, and year. Inpatients admitted with lumbar spine disease at hospitals with higher modified CMS had higher total cost per case (Estimate: 192,658 won, 95% CI: 125,701 – 259,614, p: <.0001) (Table 16). Table 17 shows the results for the adjusted effect of association between modified CMS and total cost per diem among total patients, including both surgery and non-surgery lumbar spine disease patients, adjusting for hospital type, organization type, region of hospital, number of beds, number of doctors, presence of CT, presence of MRI, presence of PET, PCCL, age, sex, residential region, surgery, death, and year. Inpatients admitted with lumbar spine disease at hospitals with higher modified CMS had higher total cost per diem (Estimate: 55,694 won, 95% CI: 46,205 – 65,183, p: <.0001) (Table 17).

Table 14. Association of Modified CMS on LOS among total patients

(Unit: days)

		Length of Stay			
		Estimate	95% CI		P-value
Hospital level					
Modified CMS		-1.700	-1.886	-1.514	<.0001
Type					
	Tertiary Hospital	1.072	0.548	1.595	<.0001
	General Hospital	0.977	0.664	1.290	<.0001
	Hospital	ref			
Organization Type					
	Public	2.135	1.418	2.852	<.0001
	Corporate	0.732	0.493	0.972	<.0001
	Private	ref			
Region					
	Metropolitan	-1.648	-1.893	-1.404	<.0001
	Urban	1.671	1.421	1.920	<.0001
	Rural	ref			
Bed					
	≤199	-1.679	-2.484	-0.874	<.0001
	200-299	-1.146	-1.911	-0.381	0.003
	300-399	-0.175	-0.966	0.615	0.664
	400-499	-1.268	-2.104	-0.432	0.003
	500-599	0.755	0.018	1.492	0.045
	600-699	0.806	0.102	1.510	0.025
	700-799	0.416	-0.244	1.076	0.216
	800-899	1.447	0.865	2.030	<.0001
	≥900	ref			
Doctor					
	≤49	1.496	0.683	2.309	0.000
	50-99	0.755	-0.042	1.552	0.063
	100-149	0.558	-0.201	1.317	0.150
	150-199	0.993	0.302	1.684	0.005
	200-249	0.307	-0.352	0.966	0.361
	250-299	0.519	-0.042	1.080	0.070
	≥300	ref			
CT					
	No	-0.190	-0.554	0.173	0.305
	Yes	ref			
MRI					
	No	1.578	1.225	1.932	<.0001
	Yes	ref			
PET					
	No	1.842	1.458	2.227	<.0001
	Yes	ref			
Individual level					
PCCL					
	0	-5.417	-6.075	-4.759	<.0001
	1	-2.293	-2.961	-1.625	<.0001
	2	-0.564	-1.254	0.126	0.109
	3	ref			
Sex					
	Male	-0.895	-1.053	-0.738	<.0001
	Female	ref			
Age					
	≤29	-2.602	-2.957	-2.248	<.0001
	30-39	-2.261	-2.567	-1.956	<.0001
	40-49	-1.409	-1.685	-1.133	<.0001
	50-59	-0.704	-0.954	-0.453	<.0001
	60-69	-0.143	-0.390	0.103	0.255
	≥70	ref			
Region					
	Metropolitan	0.252	0.006	0.497	0.044
	Urban	0.129	-0.111	0.368	0.292
	Rural	ref			
Surgery					
	Yes	ref			
	No	-3.676	-3.841	-3.511	<.0001
Death					
	Yes	ref			
	No	1.875	0.789	2.961	0.001
Year					
	2002	3.077	2.540	3.614	<.0001
	2003	2.987	2.509	3.464	<.0001
	2004	1.369	0.930	1.809	<.0001
	2005	1.521	1.132	1.910	<.0001
	2006	2.032	1.657	2.408	<.0001
	2007	1.827	1.475	2.179	<.0001
	2008	2.099	1.766	2.433	<.0001
	2009	2.207	1.887	2.528	<.0001
	2010	1.473	1.165	1.781	<.0001
	2011	0.600	0.305	0.895	<.0001
	2012	0.368	0.082	0.653	0.012
	2013	ref			

Adjusted for primary diagnosed code

Table 15. Association of Modified CMS on mortality among total patients

		Mortality			
		OR	95% CI		P-value
Hospital level					
Modified CMS		0.635	0.521	0.775	<.0001
Type					
	Tertiary Hospital	0.972	0.619	1.526	0.902
	General Hospital	0.781	0.590	1.034	0.084
	Hospital	1.000			
Organization Type					
	Public	2.122	1.389	3.243	0.001
	Corporate	1.371	1.110	1.694	0.003
	Private	1.000			
Region					
	Metropolitan	0.943	0.742	1.198	0.631
	Urban	1.151	0.920	1.440	0.219
	Rural	1.000			
Bed					
	≤199	1.506	0.701	3.234	0.294
	200-299	1.624	0.778	3.389	0.196
	300-399	1.669	0.795	3.501	0.176
	400-499	1.298	0.600	2.811	0.508
	500-599	1.033	0.511	2.089	0.928
	600-699	0.903	0.464	1.755	0.763
	700-799	0.828	0.422	1.625	0.583
	800-899	0.946	0.573	1.562	0.828
	≥900	1.000			
Doctor					
	≤49	0.651	0.302	1.402	0.272
	50-99	0.737	0.356	1.528	0.412
	100-149	0.872	0.439	1.733	0.695
	150-199	0.394	0.182	0.849	0.018
	200-249	0.461	0.228	0.930	0.031
	250-299	1.218	0.800	1.855	0.357
	≥300	1.000			
CT					
	No	0.925	0.639	1.337	0.677
	Yes	1.000			
MRI					
	No	1.589	1.229	2.055	0.000
	Yes	1.000			
PET					
	No	0.887	0.623	1.262	0.504
	Yes	1.000			
Individual level					
PCCL					
	0	0.192	0.146	0.251	<.0001
	1	0.233	0.175	0.310	<.0001
	2	0.387	0.291	0.514	<.0001
	3	1.000			
Sex					
	Male	1.472	1.269	1.707	<.0001
	Female	1.000			
Age					
	≤29	0.147	0.092	0.233	<.0001
	30-39	0.157	0.108	0.227	<.0001
	40-49	0.172	0.127	0.235	<.0001
	50-59	0.246	0.194	0.311	<.0001
	60-69	0.368	0.303	0.447	<.0001
	≥70	1.000			
Region					
	Metropolitan	0.785	0.607	1.017	0.067
	Urban	0.840	0.670	1.054	0.131
	Rural	1.000			
Surgery					
	Yes	1.000			
	No	1.599	1.343	1.903	<.0001
Death					
	Yes		N/A		
	No				
Year					
	2002	0.650	0.294	1.437	0.287
	2003	1.460	0.904	2.358	0.122
	2004	1.055	0.674	1.653	0.814
	2005	1.067	0.717	1.589	0.748
	2006	1.718	1.224	2.411	0.002
	2007	1.445	1.030	2.026	0.033
	2008	1.203	0.860	1.683	0.281
	2009	1.390	1.022	1.891	0.036
	2010	1.387	1.026	1.875	0.033
	2011	1.257	0.937	1.687	0.127
	2012	1.307	0.985	1.736	0.064
	2013	1.000			

Adjusted for primary diagnosed code

Table 16. Association of Modified CMS on total cost per case among total patients

(Unit: won)

		Total Cost per case			
		Estimate	95% CI		P-value
Hospital level					
Modified CMS		192,658	125,701	259,614	<.0001
Type					
	Tertiary Hospital	36,498	-151,664	224,661	0.704
	General Hospital	-136,847	-249,224	-24,470	0.017
	Hospital	ref			
Organization Type					
	Public	39,035	-218,763	296,832	0.767
	Corporate	50,415	-35,634	136,463	0.251
	Private	ref			
Region					
	Metropolitan	14,011	-73,934	101,956	0.755
	Urban	363,145	273,390	452,900	<.0001
	Rural	ref			
Bed					
	≤199	113,590	-175,990	403,170	0.442
	200-299	361,535	86,461	636,608	0.010
	300-399	777,216	492,934	1,061,498	<.0001
	400-499	433,116	132,565	733,666	0.005
	500-599	923,310	658,359	1,188,261	<.0001
	600-699	913,663	660,553	1,166,773	<.0001
	700-799	630,061	392,806	867,316	<.0001
	800-899	231,736	22,305	441,167	0.030
	≥900	ref			
Doctor					
	≤49	-1,101,740	-1,394,044	-809,436	<.0001
	50-99	-1,159,576	-1,445,956	-873,196	<.0001
	100-149	-776,666	-1,049,612	-503,719	<.0001
	150-199	-688,876	-937,349	-440,402	<.0001
	200-249	-595,701	-832,471	-358,932	<.0001
	250-299	-402,449	-604,097	-200,801	<.0001
	≥300	ref			
CT					
	No	-176,502	-307,268	-45,735	0.008
	Yes	ref			
MRI					
	No	-246,132	-373,295	-118,970	0.000
	Yes	ref			
PET					
	No	-94,042	-232,358	44,274	0.183
	Yes	ref			
Individual level					
PCCL					
	0	-118,002	-354,604	118,600	0.328
	1	867,483	627,182	1,107,784	<.0001
	2	1,374,079	1,125,959	1,622,200	<.0001
	3	ref			
Sex					
	Male	-92,025	-148,641	-35,408	0.001
	Female	ref			
Age					
	≤29	-946,853	-1,074,469	-819,236	<.0001
	30-39	-805,589	-915,493	-695,686	<.0001
	40-49	-656,418	-755,528	-557,309	<.0001
	50-59	-329,168	-419,209	-239,128	<.0001
	60-69	54,352	-34,364	143,068	0.230
	≥70	ref			
Region					
	Metropolitan	117,435	29,246	205,624	0.009
	Urban	-57,136	-143,192	28,921	0.193
	Rural	ref			
Surgery					
	Yes	ref			
	No	-2,008,377	-2,067,634	-1,949,121	<.0001
Death					
	Yes	ref			
	No	753,879	363,431	1,144,327	0.000
Year					
	2002	445,872	252,880	638,864	<.0001
	2003	18,560	-153,218	190,339	0.832
	2004	-437,645	-595,684	-279,607	<.0001
	2005	17,856	-122,108	157,820	0.803
	2006	1,845	-133,113	136,802	0.979
	2007	181,910	55,444	308,376	0.005
	2008	158,788	38,799	278,777	0.010
	2009	349,137	233,959	464,316	<.0001
	2010	325,841	214,972	436,709	<.0001
	2011	-30,054	-136,050	75,942	0.578
	2012	80,687	-21,842	183,217	0.123
	2013	ref			

Adjusted for primary diagnosed code

Table 17. Association of Modified CMS on total cost per diem among total patients

(Unit: won)

		Total Cost per diem			
		Estimate	95% CI		P-value
Hospital level					
Modified CMS		55,694	46,205	65,183	<.0001
Type					
	Tertiary Hospital	34,173	7,352	60,993	0.013
	General Hospital	-3,989	-19,946	11,967	0.624
	Hospital	ref			
Organization Type					
	Public	-55,363	-92,045	-18,682	0.003
	Corporate	-13,594	-25,812	-1,375	0.029
	Private	ref			
Region					
	Metropolitan	53,700	41,214	66,186	<.0001
	Urban	257	-12,491	13,005	0.969
	Rural	ref			
Bed					
	≤199	5,837	-35,385	47,060	0.781
	200-299	36,932	-2,233	76,097	0.065
	300-399	24,401	-16,087	64,889	0.238
	400-499	26,096	-16,777	68,969	0.233
	500-599	46,079	8,379	83,780	0.017
	600-699	43,418	7,372	79,464	0.018
	700-799	-13,794	-47,678	20,091	0.425
	800-899	-13,158	-42,875	16,558	0.386
	≥900	ref			
Doctor					
	≤49	-70,699	-112,364	-29,034	0.001
	50-99	-27,814	-68,628	13,000	0.182
	100-149	-60,307	-99,146	-21,468	0.002
	150-199	-63,345	-98,738	-27,952	0.001
	200-249	-52,864	-86,582	-19,145	0.002
	250-299	-46,951	-75,637	-18,265	0.001
	≥300	ref			
CT					
	No	-29,488	-48,027	-10,949	0.002
	Yes	ref			
MRI					
	No	-25,261	-43,332	-7,190	0.006
	Yes	ref			
PET					
	No	-32,219	-51,954	-12,485	0.001
	Yes	ref			
Individual level					
PCCL					
	0	56,699	22,947	90,451	0.001
	1	67,963	33,688	102,238	0.000
	2	76,577	41,194	111,959	<.0001
	3	ref			
Sex					
	Male	13,295	5,255	21,334	0.001
	Female	ref			
Age					
	≤29	-22,105	-40,214	-3,997	0.017
	30-39	-28,210	-43,818	-12,602	0.000
	40-49	-26,463	-40,542	-12,383	0.000
	50-59	-12,070	-24,864	724	0.064
	60-69	5,881	-6,720	18,482	0.360
	≥70	ref			
Region					
	Metropolitan	-7,959	-20,479	4,561	0.213
	Urban	-9,528	-21,741	2,685	0.126
	Rural	ref			
Surgery					
	Yes	ref			
	No	-100,115	-108,516	-91,715	<.0001
Death					
	Yes	ref			
	No	-30,075	-85,687	25,538	0.289
Year					
	2002	334	-26,977	27,646	0.981
	2003	-36,056	-60,374	-11,737	0.004
	2004	-4,215	-26,600	18,171	0.712
	2005	31,539	11,702	51,376	0.002
	2006	-20,933	-40,065	-1,801	0.032
	2007	-4,922	-22,839	12,995	0.590
	2008	-11,451	-28,455	5,552	0.187
	2009	-12,424	-28,740	3,893	0.136
	2010	-12,264	-27,970	3,442	0.126
	2011	-14,884	-30,049	280	0.054
	2012	6,921	-7,618	21,461	0.351
	2013	ref			

Adjusted for primary diagnosed code

Table 18 shows the results for the adjusted effect of the association between modified CMS and LOS among lumbar spine disease surgery patients adjusting for hospital type, organization type, region of hospital, number of beds, number of doctors, presence of CT, presence of MRI, presence of PET, PCCL, age, sex, residential region, death, and year. Inpatients admitted with lumbar spine disease at hospitals with higher modified CMS had a shorter LOS (Estimate: -2.539, 95% CI: -2.859–-2.220, p: <.0001) (see Appendix E1).

Table 19 shows the results of the adjusted effect of the association between modified CMS and mortality among lumbar spine disease surgery patients adjusting for hospital type, organization type, region of hospital, number of beds, number of doctors, presence of CT, presence of MRI, presence of PET, PCCL, age, sex, residential region, and year. Inpatients admitted with lumbar spine disease at hospitals with higher modified CMS had an association 0.972 times lower (95% CI: 0.837 – 1.130, p: 0.715) (see Appendix E2).

Table 20 shows the results of the adjusted effect for the association between modified CMS and total cost per case among lumbar spine disease surgery patients adjusting for hospital type, organization type, region of hospital, number of beds, number of doctors, presence of CT, presence of MRI, presence of PET, PCCL, age, sex, residential region, death, and year. Inpatients admitted with lumbar spine disease at hospitals with higher modified CMS had lower total cost per case (Estimate: -152,060 won, 95% CI: -287,236 – -16,884, p: 0.028): -556,111 won lower (95% CI: -941,978 – -170,243, p: 0.005) in tertiary hospitals and -607,487 won lower (95% CI: -847,311 – -367,662, p: <.0001) in general hospitals compared with hospitals (see Appendix E3).

Table 21 shows the results for the adjusted effect of the association between modified CMS and total cost per diem among lumbar spine disease surgery patients adjusting for hospital type, organization type, region of hospital, number of beds, number of doctors, presence of CT, presence of MRI, presence of PET, PCCL, age, sex, residential region, death, and year. Inpatients admitted with lumbar spine disease at hospitals with higher modified CMS had higher total cost per diem (Estimate: 42,362 won, 95% CI: -29,180 – 55,544, p: <.0001) (see Appendix E4).

Table 18. Association of Modified CMS on LOS among surgery patients

(Unit: days)

		Length of Stay			
		Estimate	95% CI		P-value
Hospital level					
Modified CMS		-2.539	-2.859	-2.220	<.0001
Type					
	Tertiary Hospital	-0.174	-1.085	0.737	0.708
	General Hospital	0.105	-0.461	0.671	0.716
	Hospital	ref			
Organization Type					
	Public	6.398	4.873	7.924	<.0001
	Corporate	1.030	0.582	1.479	<.0001
	Private	ref			
Region					
	Metropolitan	-2.291	-2.694	-1.888	<.0001
	Urban	1.714	1.302	2.125	<.0001
	Rural	ref			
Bed					
	≤199	-2.083	-3.520	-0.646	0.005
	200-299	-0.997	-2.349	0.356	0.149
	300-399	0.580	-0.852	2.012	0.427
	400-499	0.073	-1.465	1.611	0.926
	500-599	1.112	-0.171	2.394	0.089
	600-699	1.140	-0.091	2.370	0.070
	700-799	0.616	-0.478	1.711	0.270
	800-899	0.576	-0.363	1.516	0.229
	≥900	ref			
Doctor					
	≤49	0.517	-0.910	1.945	0.478
	50-99	0.870	-0.536	2.275	0.225
	100-149	0.163	-1.112	1.437	0.802
	150-199	1.515	0.380	2.651	0.009
	200-249	0.935	-0.164	2.034	0.095
	250-299	1.344	0.410	2.279	0.005
	≥300	ref			
CT					
	No	-0.898	-1.512	-0.284	0.004
	Yes	ref			
MRI					
	No	3.650	2.718	4.581	<.0001
	Yes	ref			
PET					
	No	2.824	2.154	3.495	<.0001
	Yes	ref			
Individual level					
PCCL					
	0	-3.120	-4.262	-1.979	<.0001
	1	-0.513	-1.665	0.639	0.383
	2	1.396	0.210	2.582	0.021
	3	ref			
Sex					
	Male	-1.363	-1.631	-1.096	<.0001
	Female	ref			
Age					
	≤29	-3.557	-4.204	-2.911	<.0001
	30-39	-3.053	-3.589	-2.516	<.0001
	40-49	-1.871	-2.336	-1.405	<.0001
	50-59	-1.177	-1.587	-0.767	<.0001
	60-69	-0.980	-1.374	-0.585	<.0001
	≥70	ref			
Region					
	Metropolitan	0.618	0.221	1.015	0.002
	Urban	0.526	0.145	0.908	0.007
	Rural	ref			
Death					
	Yes	ref			
	No	1.398	-1.047	3.844	0.263
Year					
	2002	1.424	0.525	2.323	0.002
	2003	0.894	0.091	1.698	0.029
	2004	-0.863	-1.600	-0.127	0.022
	2005	-0.164	-0.810	0.482	0.618
	2006	0.228	-0.404	0.860	0.479
	2007	0.127	-0.465	0.719	0.675
	2008	0.658	0.081	1.235	0.025
	2009	0.965	0.411	1.520	0.001
	2010	0.641	0.101	1.182	0.020
	2011	0.407	-0.125	0.938	0.134
	2012	0.368	-0.153	0.889	0.167
	2013	ref			

Adjusted for primary diagnosed code

Table 19. Association of Modified CMS on mortality among surgery patients

		Mortality			
		OR	95% CI		P-value
Hospital level					
Modified CMS		0.972	0.837	1.130	0.715
Type					
	Tertiary Hospital	1.054	0.693	1.602	0.805
	General Hospital	0.934	0.718	1.216	0.612
	Hospital	1.000			
Organization Type					
	Public	0.888	0.421	1.873	0.755
	Corporate	1.095	0.892	1.346	0.384
	Private	1.000			
Region					
	Metropolitan	1.003	0.833	1.209	0.974
	Urban	1.053	0.872	1.272	0.590
	Rural	1.000			
Bed					
	≤199	1.164	0.593	2.282	0.659
	200-299	1.155	0.612	2.177	0.656
	300-399	1.367	0.708	2.640	0.350
	400-499	1.083	0.529	2.218	0.827
	500-599	0.922	0.503	1.691	0.794
	600-699	1.060	0.607	1.853	0.837
	700-799	0.888	0.526	1.498	0.654
	800-899	1.048	0.695	1.580	0.824
	≥900	1.000			
Doctor					
	≤49	0.960	0.494	1.869	0.905
	50-99	1.036	0.541	1.986	0.915
	100-149	1.134	0.639	2.014	0.666
	150-199	0.925	0.540	1.583	0.775
	200-249	0.855	0.505	1.446	0.557
	250-299	1.209	0.811	1.801	0.350
	≥300	1.000			
CT					
	No	0.997	0.743	1.337	0.983
	Yes	1.000			
MRI					
	No	0.919	0.573	1.476	0.719
	Yes	1.000			
PET					
	No	0.930	0.685	1.261	0.638
	Yes	1.000			
Individual level					
PCCL					
	0	0.570	0.381	0.853	0.006
	1	0.569	0.378	0.856	0.007
	2	0.730	0.480	1.111	0.142
	3	1.000			
Sex					
	Male	1.028	0.908	1.163	0.662
	Female	1.000			
Age					
	≤29	0.776	0.570	1.056	0.106
	30-39	0.781	0.607	1.005	0.055
	40-49	0.784	0.632	0.972	0.027
	50-59	0.820	0.682	0.986	0.035
	60-69	0.855	0.719	1.017	0.077
	≥70	1.000			
Region					
	Metropolitan	0.921	0.762	1.113	0.390
	Urban	0.904	0.755	1.083	0.270
	Rural	1.000			
Death					
	Yes		N/A		
	No				
Year					
	2002	0.985	0.636	1.525	0.945
	2003	1.025	0.698	1.503	0.901
	2004	0.966	0.680	1.373	0.849
	2005	0.978	0.720	1.329	0.887
	2006	1.188	0.894	1.579	0.235
	2007	1.048	0.795	1.382	0.740
	2008	1.011	0.771	1.327	0.935
	2009	1.023	0.789	1.327	0.861
	2010	1.056	0.821	1.359	0.669
	2011	1.079	0.843	1.380	0.546
	2012	1.039	0.814	1.326	0.759
	2013	1.000			

Adjusted for primary diagnosed code

Table 20. Association of Modified CMS on total cost per case among surgery patients

(Unit: won)

		Total Cost per case			
		Estimate	95% CI		P-value
Hospital level					
Modified CMS		-152,060	-287,236	-16,884	0.028
Type					
	Tertiary Hospital	-556,111	-941,978	-170,243	0.005
	General Hospital	-607,487	-847,311	-367,662	<.0001
	Hospital	ref			
Organization Type					
	Public	1,088,659	442,452	1,734,866	0.001
	Corporate	242,019	52,108	431,930	0.013
	Private	ref			
Region					
	Metropolitan	-242,075	-412,721	-71,429	0.005
	Urban	436,402	262,067	610,738	<.0001
	Rural	ref			
Bed					
	≤199	383,062	-225,631	991,755	0.217
	200-299	894,820	321,946	1,467,694	0.002
	300-399	2,105,382	1,498,953	2,711,811	<.0001
	400-499	1,021,570	370,019	1,673,121	0.002
	500-599	1,615,999	1,072,747	2,159,252	<.0001
	600-699	1,487,516	966,234	2,008,798	<.0001
	700-799	1,123,535	659,916	1,587,153	<.0001
	800-899	83,899	-314,109	481,908	0.680
	≥900	ref			
Doctor					
	≤49	-1,822,744	-2,427,467	-1,218,020	<.0001
	50-99	-1,580,249	-2,175,391	-985,108	<.0001
	100-149	-1,227,326	-1,767,187	-687,465	<.0001
	150-199	-1,056,423	-1,537,319	-575,527	<.0001
	200-249	-720,735	-1,186,291	-255,179	0.002
	250-299	-270,308	-666,237	125,621	0.181
	≥300	ref			
CT					
	No	-394,287	-654,359	-134,215	0.003
	Yes	ref			
MRI					
	No	498,394	103,812	892,975	0.013
	Yes	ref			
PET					
	No	115,532	-168,434	399,499	0.425
	Yes	ref			
Individual level					
PCCL					
	0	1,297,466	813,965	1,780,966	<.0001
	1	2,280,018	1,792,037	2,767,999	<.0001
	2	2,978,026	2,475,627	3,480,424	<.0001
	3	ref			
Sex					
	Male	-204,567	-317,899	-91,236	0.000
	Female	ref			
Age					
	≤29	-1,489,142	-1,762,981	-1,215,304	<.0001
	30-39	-1,297,855	-1,525,170	-1,070,540	<.0001
	40-49	-1,121,956	-1,319,066	-924,846	<.0001
	50-59	-627,865	-801,662	-454,069	<.0001
	60-69	-319,843	-486,857	-152,828	0.000
	≥70	ref			
Region					
	Metropolitan	379,186	210,934	547,439	<.0001
	Urban	-23,903	-185,442	137,636	0.772
	Rural	ref			
Death					
	Yes	ref			
	No	192,243	-843,766	1,228,252	0.716
Year					
	2002	353,426	-27,383	734,235	0.069
	2003	-603,129	-943,381	-262,877	0.001
	2004	-1,218,983	-1,531,063	-906,903	<.0001
	2005	-285,711	-559,228	-12,194	0.041
	2006	-462,273	-729,985	-194,562	0.001
	2007	-215,000	-465,698	35,697	0.093
	2008	-207,560	-451,905	36,786	0.096
	2009	13,720	-221,323	248,764	0.909
	2010	210,149	-18,883	439,180	0.072
	2011	-259,622	-484,610	-34,634	0.024
	2012	122,582	-98,188	343,351	0.277
	2013	ref			

Adjusted for primary diagnosed code

Table 21. Association of Modified CMS on total cost per diem among surgery patients

(Unit: won)

		Total Cost per diem			
		Estimate	95% CI		P-value
Hospital level					
Modified CMS		42,362	29,180	55,544	<.0001
Type					
	Tertiary Hospital	-13,852	-51,510	23,807	0.471
	General Hospital	-40,224	-63,617	-16,831	0.001
	Hospital	ref			
Organization Type					
	Public	-99,631	-162,991	-36,271	0.002
	Corporate	-14,342	-32,866	4,182	0.129
	Private	ref			
Region					
	Metropolitan	70,206	53,560	86,851	<.0001
	Urban	-98	-17,099	16,903	0.991
	Rural	ref			
Bed					
	≤199	85,483	26,117	144,850	0.005
	200-299	120,529	64,661	176,397	<.0001
	300-399	140,659	81,513	199,804	<.0001
	400-499	71,297	7,625	134,968	0.028
	500-599	81,848	28,856	134,840	0.003
	600-699	47,037	-3,807	97,880	0.070
	700-799	14,678	-30,571	59,926	0.525
	800-899	-7,969	-46,819	30,881	0.688
	≥900	ref			
Doctor					
	≤49	-117,550	-176,549	-58,550	<.0001
	50-99	-12,031	-70,106	46,044	0.685
	100-149	-79,750	-132,426	-27,074	0.003
	150-199	-102,637	-149,562	-55,713	<.0001
	200-249	-72,211	-117,699	-26,723	0.002
	250-299	-72,847	-111,468	-34,226	0.000
	≥300	ref			
CT					
	No	-41,399	-66,756	-16,042	0.001
	Yes	ref			
MRI					
	No	-72,968	-111,440	-34,497	0.000
	Yes	ref			
PET					
	No	-71,770	-99,496	-44,045	<.0001
	Yes	ref			
Individual level					
PCCL					
	0	85,335	38,194	132,476	0.000
	1	96,686	49,109	144,264	<.0001
	2	107,110	58,126	156,095	<.0001
	3	ref			
Sex					
	Male	8,607	-2,447	19,660	0.127
	Female	ref			
Age					
	≤29	20,318	-6,389	47,025	0.136
	30-39	2,101	-20,065	24,266	0.853
	40-49	-24,467	-43,690	-5,243	0.013
	50-59	-11,936	-28,887	5,015	0.168
	60-69	-535	-16,825	15,754	0.949
	≥70	ref			
Region					
	Metropolitan	4,398	-12,015	20,811	0.599
	Urban	-15,319	-31,071	432	0.057
	Rural	ref			
Death					
	Yes	ref			
	No	-109,424	-211,293	-7,554	0.035
Year					
	2002	-3,158	-40,295	33,979	0.868
	2003	-58,710	-91,892	-25,528	0.001
	2004	-25,643	-56,112	4,826	0.099
	2005	54,176	27,499	80,852	<.0001
	2006	-38,413	-64,532	-12,295	0.004
	2007	-30,744	-55,193	-6,295	0.014
	2008	-56,316	-80,145	-32,487	<.0001
	2009	-58,672	-81,595	-35,749	<.0001
	2010	-38,254	-60,594	-15,913	0.001
	2011	-50,741	-72,695	-28,787	<.0001
	2012	-8,038	-29,570	13,493	0.464
	2013	ref			

Adjusted for primary diagnosed code

Table 22 shows the results of subgroup analysis for the adjusted effect of the association between modified CMS and hospital cost components per case by hospital type, adjusting for hospital type, organization type, region of hospital, number of beds, number of doctors, presence of CT, presence of MRI, presence of PET, PCCL, age, sex, residential region, surgery, death, and year. Inpatients admitted with lumbar spine disease at hospitals with higher modified CMS had lower cost components per case except for medication cost and procedure and surgery cost (admission cost: -66,900 won, p: <.0001; injection cost: -119,014 won, p: <.0001; anesthesia cost: -13,963 won, p: <.0001; examination cost: -11,276 won, p: 0.015) (see Appendix E5).

Table 23 shows the results of subgroup analysis for the adjusted effect of the association between modified CMS and hospital cost components per diem by hospital type adjusting for hospital type, organization type, region of hospital, number of beds, number of doctors, presence of CT, presence of MRI, presence of PET, PCCL, age, sex, residential region, surgery, death, and year. Inpatients admitted with lumbar spine disease at hospitals with higher modified CMS had higher cost components except for injection cost per diem (injection cost: -2,742 won, p: 0.001; admission cost: 3,143 won, p: <.0004; medication cost : 2,070 won, p: <.0001; anesthesia cost: 2,045 won, p: <.0001; procedure or surgery cost: 37,273 won, p: <.0001; examination cost: 572 won, p: 0.086) (see Appendix E6).

Table 22. Association of Modified CMS on each cost component per case by hospital type

(Unit: won)

	Total hospital				≥ General hospital				Hospital			
	Estimate	95% CI		P-value	Estimate	95% CI		P-value	Estimate	95% CI		P-value
Total												
Admission cost per case	-13,603	9,853	-32,915	0.167	-17,475	-85,904	50,954	0.617	-10,372	-27,007	6,263	0.222
Medication cost per case	6,370	3,549	9,192	<.0001	10,648	476	20,820	0.040	5,707	3,353	8,060	<.0001
Injection cost per case	-35,240	-47,863	-22,618	<.0001	-6,419	-49,297	36,459	0.769	-35,886	-47,434	-24,339	<.0001
Anesthesia cost per case	19,511	15,835	23,188	<.0001	39,675	28,452	50,898	<.0001	13,810	10,041	17,578	<.0001
Procedure or surgery cost per case	215,751	176,271	255,231	<.0001	247,848	123,067	372,629	<.0001	192,232	153,298	231,165	<.0001
Examination cost per case	-132	-4,796	4,532	0.956	1,037	-16,538	18,612	0.908	638	-2,850	4,127	0.720
Surgery patients												
Admission cost per case	-66,900	-105,724	-28,077	0.001	-112,646	-264,560	39,268	0.146	-54,783	-87,470	-22,095	0.001
Medication cost per case	1,743	-3,712	7,197	0.531	8,174	-13,340	29,688	0.456	1,625	-2,888	6,137	0.480
Injection cost per case	-119,014	-145,949	-92,079	<.0001	-117,327	-216,514	-18,140	0.020	-116,807	-141,477	-92,137	<.0001
Anesthesia cost per case	-13,963	-20,969	-6,958	<.0001	-10,346	-33,425	12,734	0.380	-14,445	-21,564	-7,327	<.0001
Procedure or surgery cost per case	57,351	-22,829	137,532	0.161	-170,034	-442,572	102,505	0.221	63,138	-15,223	141,498	0.114
Examination cost per case	-11,276	-20,336	-2,216	0.015	-19,092	-55,581	17,398	0.305	-10,231	-17,254	-3,208	0.004

***Adjusted for all variables**

Table 23. Association of Modified CMS on each cost component per diem by hospital type

(Unit: won)

	Total hospital				≥ General hospital				Hospital			
	Estimate	95% CI		P-value	Estimate	95% CI		P-value	Estimate	95% CI		P-value
Total												
Admission cost per diem	5,164	2,640	7,687	<.0001	11,795	2,466	21,124	0.013	3,803	1,751	5,854	0.000
Medication cost per diem	1,943	1,578	2,308	<.0	3,248	1,914	4,582	<.0001	1,709	1,407	2,011	<.0001
Injection cost per diem	1,319	71	2,567	0.038	3,192	-1,396	7,780	0.173	944	-78	1,966	0.070
Anesthesia cost per diem	4,281	3,638	4,924	<.0001	8,258	5,940	10,577	<.0001	3,041	2,498	3,584	<.0001
Procedure or surgery cost per diem	41,908	36,023	47,793	<.0001	57,177	36,623	77,731	<.0001	35,932	30,713	41,151	<.0001
Examination cost per diem	1,079	243	1,915	0.011	4,050	630	7,470	0.020	582	74	1,091	0.025
Surgery patients												
Admission cost per diem	3,143	985	5,301	0.004	10,332	2,875	17,789	0.007	2,636	505	4,767	0.015
Medication cost per diem	2,070	1,704	2,436	<.0001	3,886	2,634	5,139	<.0001	1,874	1,510	2,237	<.0001
Injection cost per diem	-2,742	-4,350	-1,133	0.001	-3,416	-9,623	2,790	0.281	-2,789	-4,179	-1,399	<.0001
Anesthesia cost per diem	2,045	1,117	2,973	<.0001	5,490	1,739	9,240	0.004	1,222	474	1,970	0.001
Procedure or surgery cost per diem	37,273	27,115	47,430	<.0001	35,845	-3,730	75,420	0.076	33,423	24,846	42,000	<.0001
Examination cost per diem	572	-81	1,226	0.086	2,550	88	5,012	0.042	116	-468	700	0.698

***Adjusted for all variables**

VI. Discussion

1. Discussion of Study Methods

In this study, we examined the associations between modified CMS and LOS, mortality, total cost per case, and total cost per diem, including anesthesia cost, procedure or surgery cost, injection cost, examination cost, admission cost and medication cost as dependent variables.

Taking into account the nature of the cohort sample data, which excluded convalescent hospitals, Chinese medicine clinics, and mental hospital, criteria of claim number and outliers are not considered. In addition, to calculate the hospital specialization index for lumbar spine disease hospitals, a minimum of one case of lumbar spine disease was set based on the primary ICD coding of related diseases. All results were adjusted for variables such as hospital type, organization type, region of hospital, number of beds, number of doctors, presence of CT, presence of MRI, presence of PET, PCCL, age, sex, residential region, surgery, death, and year dummy using 2002–2013 national health insurance service-national sample cohort data.

To measure hospital specialization for specific disease categories within each hospital, we developed modified CMS by taking log transformation to the denominator of CMS. Under the assumption that hospitals can provide treatments in several different diagnosis categories[27] and may be medically specialized in each of them, independently of the hospital's degree of diversification, we classified a hospital as specialized if the number of treated cases in a given diagnosis category exceeded a defined threshold (mean number of patients treated nationally in each disease category). In short, we focused on the volume as well as the proportion of patients in each diagnosis category.

Distribution of hospital by absolute number of lumbar spine disease inpatients has a positive association with modified CMS, although IHI, ITI, CMS, and ICMS have negative associations with absolute number of lumbar spine disease inpatients. In addition, we analyzes hospital clusters with modified CMS, and in cluster 3, with high hospital specialization (both high volume and proportion of lumbar spine disease patients), it was observed that relative model fit was excellent.

Thus, we select modified CMS as a Korean hospital specialization measure and conduct a generalized estimating equation (GEE) regression model accounting for correlation among individuals within each hospital to investigate association between modified CMS and LOS, mortality, total cost per case, and total cost per diem. This is a very flexible approach to the analysis of correlated data from the same subject (i.e., person) over time.[48,49]

2. Discussion of Study Results

In this study, our primary purpose was to modify medical specialization in Korea by category for lumbar spine disease hospital inpatients and to determine the effects of specialization on LOS, mortality, hospital cost per case, and hospital cost per diem after adjusting for hospital type, organization type, region of hospital, number of beds, number of doctors, presence of CT, presence of MRI, presence of PET, PCCL, age, sex, residential region, surgery, death, and year, applying a longitudinal model to a nationally representative cohort sample data from 2002 to 2013 in. To our knowledge, this is the first study anywhere in the world to develop a measure for hospital specialization in a specific disease based on patient volumes and patient proportions. As can be seen in Figure 3-4, modified CMS shows a U-shaped trend from small to large hospitals, associated with higher hospital specialization.

Our measures are therefore the first to capture our experience, professional expertise and technical equipment as well as the concentration of diagnoses within each diagnosis category, and also to show that, on balance, modified CMS provides an intuitively reasonable characterization of hospital specialization reflecting the Korean health care environment. The results of our repeated cross-sectional regression analysis over time (i.e., the GEE methodology) provide insightful scientific evidence into the associations between the modified CMS and LOS, mortality, hospital cost per case, and hospital cost per diem in current practice in Korea.

The major findings of our study are as follows. First, concepts from existing hospital specialization indexes such as IHI and ITI that are measured in terms of the proportion of total patients who are lumbar spine disease patients show the highest correlation between both IHI and ITI and proportion of total patients who are lumbar spine disease patients. However our modified CMS shows the highest correlation with absolute number of lumbar spine disease patients (Table 8). In particular, subgroup analysis by proportion of total patients who are lumbar spine disease patients reflects the results of correlation analysis between hospital specialization index and absolute hospital volume of lumbar spine disease patients. As can be seen in Table 9, IHI, ITI, CMS, and ICMS have negative associations with absolute number of lumbar spine patients, and only modified CMS has a positive association with it (Table 9). In addition, applying modified CMS on cluster 3, considered to represent specialty hospitals, excellent model fit was observed (Table 11).

Second, results of the adjusted effects of the associations between modified CMS and LOS, mortality, total cost per case, and total cost per diem among lumbar spine disease surgery patients show that inpatients at hospitals with higher modified CMS had lower LOS, lower mortality (although not significantly), and lower total cost per case, while inpatients at hospitals with higher modified CMS had higher total cost per diem. However, the results for the adjusted effects of associations between modified CMS and LOS, mortality, total cost per case, and total cost per diem among lumbar spine disease non-surgery patients show that inpatients at hospitals with higher modified CMS had lower LOS and mortality but higher total cost per case and total cost per diem.

Given the decreases in LOS, morality (although not significant) and total cost per case of lumbar spine disease surgery patients and the increase in total cost per diem of lumbar spine disease surgery patients, specialization can be considered to improve the health outcomes of these patients, reflecting the use of the very complex and sophisticated medical technologies and of the efficient and effective care and operating proedures adopted at more specialized hospitals, although non-surgical patients not requiring complex medical interventions are relatively likely to require long-term management needs for issues such as ache. As a result of our study, it can be concluded that hospital specialization has a substantial effect on hospital performance in the areas of LOS, mortality, and total cost.

Whereas previous studies, for example by Luft et al.[16] and Melnick et al.[50] found that hospitals have a tendency to imitate competitors, they also found that hospital competition tended to increase hospital specialization, resulting in increasing efficiency by reducing the costs associated with the prior service mix. In addition, several hospitals within more competitive markets had less specialized service mix, suggesting that they provide a wider range of services. These findings imply that hospitals tend to adopt some high-visibility services offered by their competitors for competitive purposes at the same time that they focus on filling selected market niches.

Also, previous studies by Grosskopf et al.[51] and Lee et al.[1] that compared the efficiency of teaching and nonteaching hospitals also show that the efficiency scores of teaching hospital were lower than those of nonteaching hospitals. However, Lindlbauer et al.[27] found efficiency to be negatively associated with case-mix specialization using measures such as IHI and ITI, but positively associated with CMS and ICMS, unlike the findings of several previous studies.[1,24] These study results imply that teaching hospitals, which tend to provide a wide range of services and use more input than non-teaching hospitals, and also large hospitals and general hospitals showed less specialization than hospitals because of the use of measures of specialization based on patient proportions rather than patient volumes.

According to many researchers, there are two opposite perspectives on hospital specialization. The first perspective argues that hospital specialization improves quality of care and efficiency of hospital management by increasing productivity[52,53] and has a positive effect on hospital performance.[42] In addition, as shown by Schneider et al.,[54] specialized hospitals are associated with higher operating margins and lower operating costs. However, contrary to the expectation that specialized hospitals reduce the overall operating profits of general hospitals, general hospital residing in markets with at least one specialized hospital have higher profit and operating margins than those that do not compete with specialized hospitals. This is consistent with prevailing economic theory, which suggests that firms will enter markets in which profit margins will be comparatively higher. In addition, economic theory predicts that competition eventually should lead hospitals to reduce the range of services they offer[26] and concentrate on services in which they have a comparative advantage.[26] In this way, each hospital finds a way to most efficiently provide given services. The other implication of this perspective is that general hospitals are threatened by specialized hospitals, because specialized hospitals tend to focus on services with high profit margins and to avoid health care services with high expenses related to admitting patients in severe condition.[55,56]

Based on the results of previous studies[22,33] showing that hospital specialization brings a reduction of production costs and results in improved efficiency of hospital operation, our results show that hospital specialization supports the achievement of hospital efficiency and increased quality of care in areas such as LOS and mortality. Continuous monitoring and further study on the same sample are still necessary, however.

3. Implications of this study

Our results have several major implications for health care policymakers and hospital administrators, in Korea and elsewhere.

First, this study may help hospital policymakers and hospital administrators to understand the effects of hospital specialization strategy on hospital cost and quality of care under recent changes in the Korean health care environment such as the initiation of the specialty hospital designation and prospective payment systems (e.g., DRG) and to evaluate the internal and external environments of the hospital before implementing a new hospital management strategy.[57] Thus, our results can help hospitals improve performance and operations.

Second**,** with increasing competition, economic crisis, and recent policy changes made by the Korean government, hospitals have to become more competitive to survive and have to seek to improve cost efficiency in the face of increasing national health expenditures and to have the desire to provide high-quality. Therefore, our findings add to the evidence of associations between hospital specialization and hospital cost per case, hospital cost per diem, LOS, and mortality, through the use of “modified CMS”; and these results enhance the evidentiary documentation for hospital specialization. However, to strengthen the reliability and generalizability of our findings of this study, replication of this work using other countries’ data could be necessary and further study of our modified CMS is needed.

4. Limitation of this study

This study has several limitations worth noting, and caution must be taken when interpreting the study`s results or attempting to generalize our findings.

First, although this study analyzed nationwide cohort sample data to measure hospital specialization during a defined period, international generalizability is limited as a result. Second, this study analyzed hospital cost, LOS, and mortality to find out whether hospital specialization is associated with hospital performance. However, it was not able to measure the direct management achievements of hospitals because of lack of information. Therefore, if data to measure financial performance of hospitals can be collected and analyzed, meaningful conclusions for policymakers and hospital administrators can be drawn. Third, when participants were selected for our study, ICD coding was employed. However, because the hospital specialization variable relied on ICD coding of principal diagnosis, it is difficult to validate individual ICD codes, because our data are anonymized database, making them susceptible to errors related to coding. Fourth, as this is a large, longitudinal, nationwide sample, there may be significant heterogeneity in the care provided both in the field and at receiving hospitals, although we limited our analysis to lumbar spine disease patients with surgery. Fifth, several unmeasured confounders exist, including hospital factors that could contribute to differences in hospital cost, mortality, and length of stay, such as better management of health resources, a well-selected care team, and presence of clinical pathways; lack of data on these means that we could not obtain information regarding unmeasured hospital characteristics. Therefore, further research is required to explore their respective contributions, because the evidence at present is inadequate and unclear.

VII. Conclusion

Our longitudinal study using 2002–2013 nationally representative health insurance service-national sample cohort data from South Korea suggests that modified CMS for a specific disease (in this case, lumbar spine disease) based on patient volumes and patient proportions showed U-shaped trends between hospital specialization and variables related to hospital scale (size and type), such as number of beds and hospital type, and that the goodness-of-fit of modified CMS is excellent. Thus, we investigated whether modified CMS was related to hospital cost per case, hospital cost per diem, LOS, and/or mortality after adjusting for hospital type, organization type, region of hospital, number of beds, number of doctors, presence of CT, presence of MRI, presence of PET, PCCL, age, sex, residential region, death, and year. The results showed that increase in hospital specialization had a substantial effect on decrease in hospital cost per case, LOS, and mortality, and on increase in hospital cost per diem among lumbar spine disease surgery patients.

With increasing competition among Korean hospitals and recent policy changes by the Korean government, considered above, our results may help hospital policymakers better understand the effects of hospital specialization strategies on hospital operations and quality of care. Our findings also provide unique evidentiary documentation of the effectiveness of our modified CMS. Thus, to strengthen the reliability and generalizability of our findings of this study, replication of this work using other countries' data could be necessary and further study of our modified CMS is needed.

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Appendix

Appendix A1. Diagnosed Code of Lumbar Spine Disease Patients

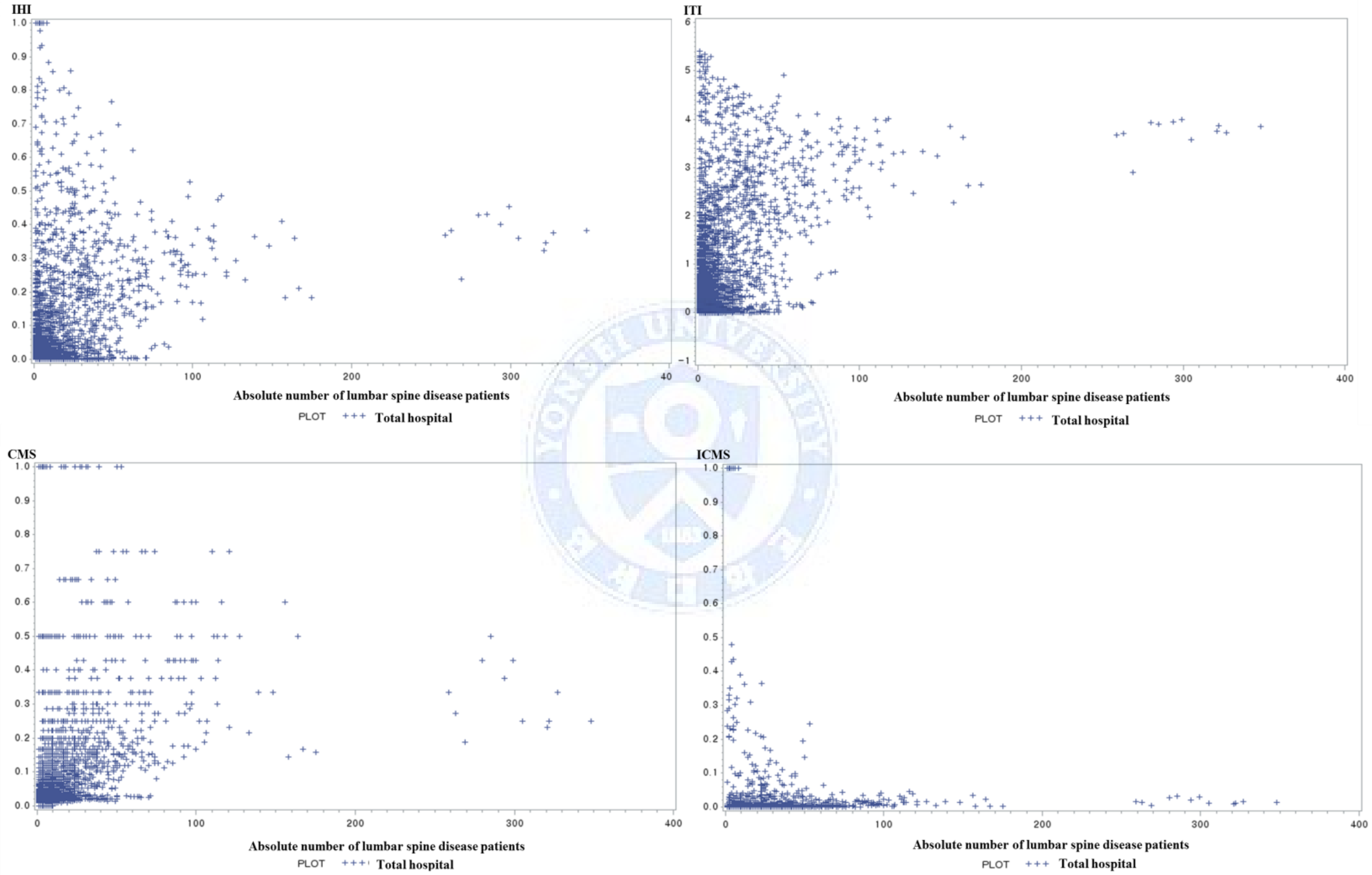
Diagnosed Code	Diagnosis
M43	Other deforming dorsopathies
M430	Spondylolysis
M4300	Spondylolysis, multiple sites in spine
M4305	Spondylolysis, thoracclumbar region
M4306	Spondylolysis, lumbar region
M4307	Spondylolysis, lumbosacral region
M4308	Spondylolysis, sacral and sacroccygeal region
M4309	Spondylolysis, site unspecified
M431	Spondylolisthesis
M4310	Spondylolisthesis, multiple sites in spine
M4315	Spondylolisthesis, thoracolumbar region
M4316	Spondylolisthesis, lumbar region
M4317	Spondylolisthesis, lumbosacral region
M4318	Spondylolisthesis, sacral and sacrococcygeal region
M4319	Spondylolisthesis, site unspecified
M432	Other fusion of spine
M4320	Other fusion of spine, multiple sites in spine
M4325	Other fusion of spine, thoracclumbar region
M4326	Other fusion of spine, lumbar region
M4327	Other fusion of spine, lumbosacral region
M4328	Other fusion of spine, sacral and sacroccygeal region
M4329	Other fusion of spine, site unspecified
M438	Other specified deforming dorsopathies
M4380	Other specified deforming dorsopathies, multiple sites in spine
M4385	Other specified deforming dorsopathies, thoracolumbar region
M4386	Other specified deforming dorsopathies, lumbar region
M4387	Other specified deforming dorsopathies, lumbosacral region
M4388	Other specified deforming dorsopathies, sacral and sacroccygeal region
M4389	Other specified deforming dorsopathies, site unspecified
M439	Deforming dorsopathy, unspecified
M4390	Deforming dorsopathy, unspecified, multiple sites in spine
M4395	Deforming dorsopathy, unspecified, thoracolumbar region
M4396	Deforming dorsopathy, unspecified, lumbar region
M4397	Deforming dorsopathy, unspecified, lumbosacral region
M4398	Deforming dorsopathy, unspecified, sacral and sacrococcygeal region
M4399	Deforming dorsopathy, unspecified, site unspecified
M48	Other spondylopathies
M480	Spinal stenosis
M4800	Spinal stenosis, multiple sites in spine
M4805	Spinal stenosis, thoracolumbar region
M4806	Spinal stenosis, lumbar region
M4807	Spinal stenosis, lumbosacral region
M4808	Spinal stenosis, sacral and sacrococcygeal region
M4809	Spinal stenosis, site unspecified
M488	Other specified spondylopathis
M4880	Other specified spondylopathies, multiple sites in spine
M4885	Other specified spondylopathies, thoracolumbar region
M4886	Other specified spondylopathies, lumbar region
M4887	Other specified spondylopathies, lumbosacral region
M4888	Other specified spondylopathies, sacral and sacrococcygeal region
M4889	Other specified spondylopathies, site unspecified
M489	Spondylopathy, unspecified

M4890	Spondylopathy, unspecified, multiple sites in spine
M4895	Spondylopathy, unspecified, thoracolumbar region
M4896	Spondylopathy, unspecified, lumbar region
M4897	Spondylopathy, unspecified, lumbosacral region
M4898	Spondylopathy, unspecified, sacral and sacrococcygeal region
M4899	Spondylopathy, unspecified, site unspecified
M51	Other intervertebral disc disorders
M510	Lumbar and other intervertegral disc disorders with myelopathy
M511	Lumbar and other intervertegral disc disorders with radiculopathy
M512	Other specified intervertebral disc displacement
M513	Other specified intervertebral disc degeneration
M514	Schmorl`s nodes
M518	Other specified intervertebral disc disorders
M519	Intervertebral disc disorder, unspecified

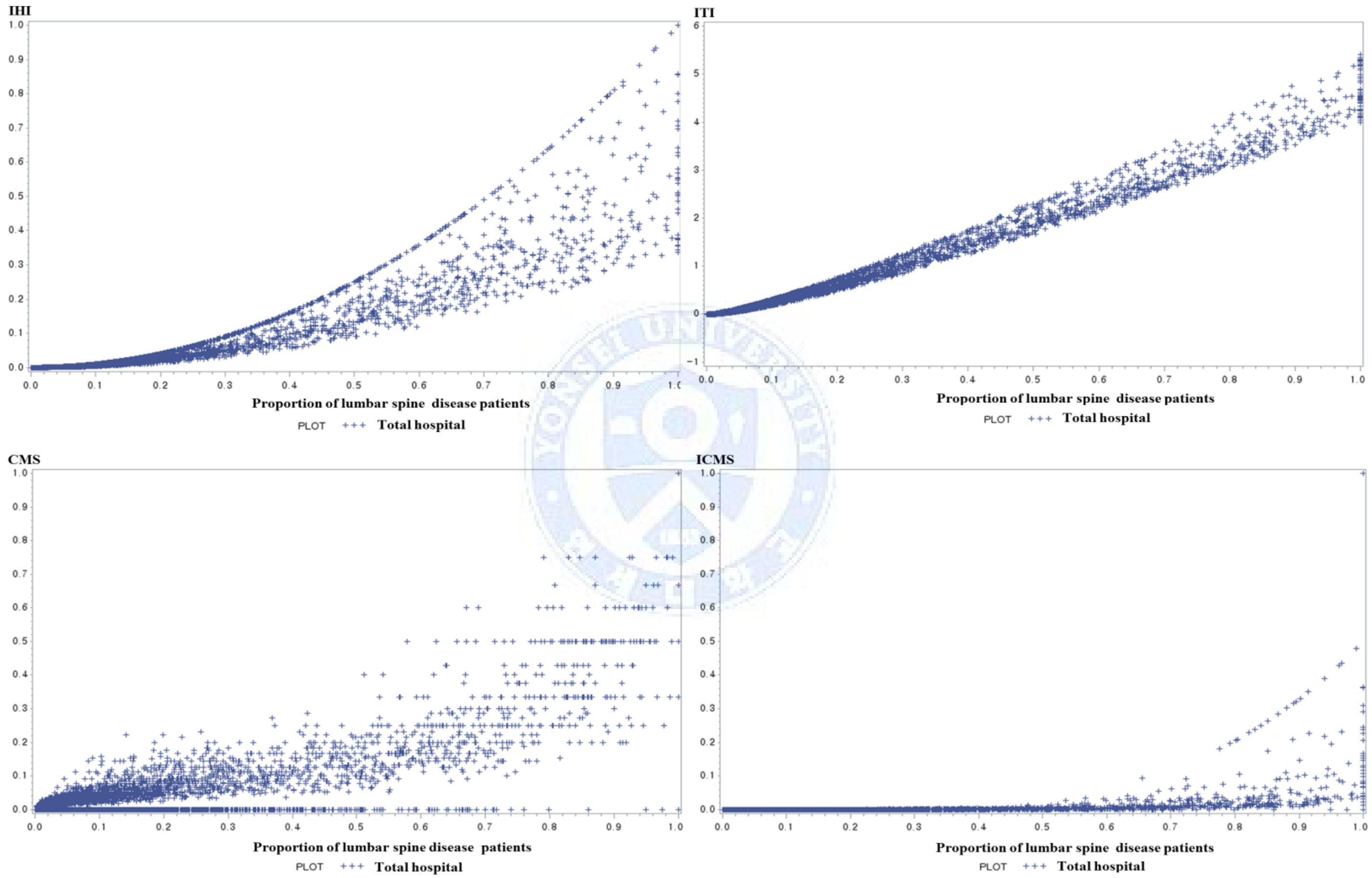
Appendix A2. Surgery Code of Lumbar Spine Disease Patients

Surgery		Procedure code
Arthrodesis For Spinal Deformity	Anterior Technique	N0444
		N0445
Arthrodesis For Spinal Deformity	Posterior Technique	N0446
		N0447
Arthrodesis of Spine	Anterior Technique (Lumbar Spine)	N0466
Arthrodesis of Spine	Posterior Technique (Lumbar Spine)	N0469
Diskectomy	Invasive (Lumbar Spine)	N1493
Diskectomy	Endoscopy	N1494
Injection Procedure	Chemonucleolysis	N1495
Aspiration Procedure	Nucleus Pulposus of Intervertebral Disk	N1496
Laminectomy	Lumbar Spine	N1499

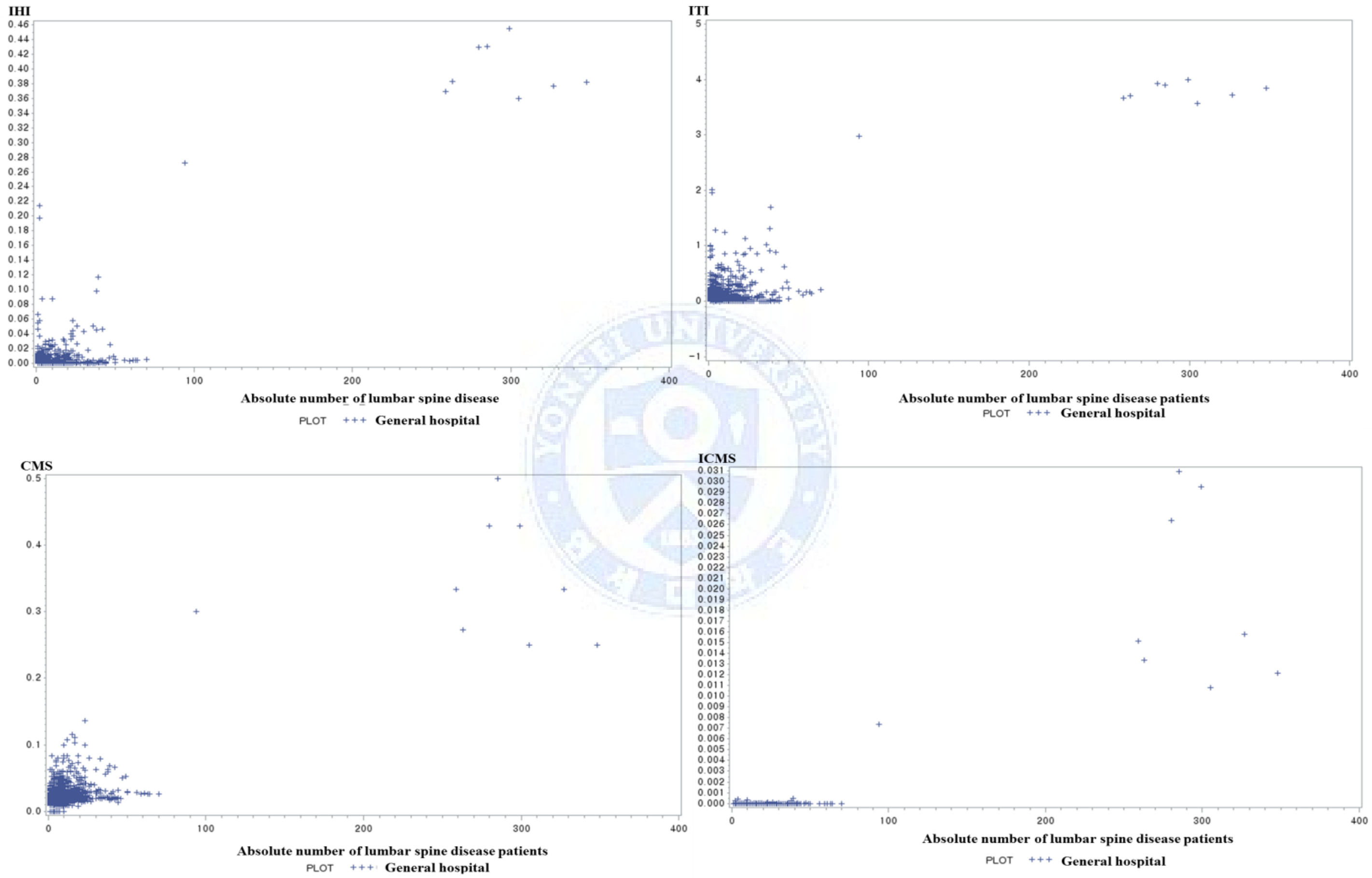
Appendix B1. Hospital specialization and absolute number of lumbar spine disease patients among total hospital



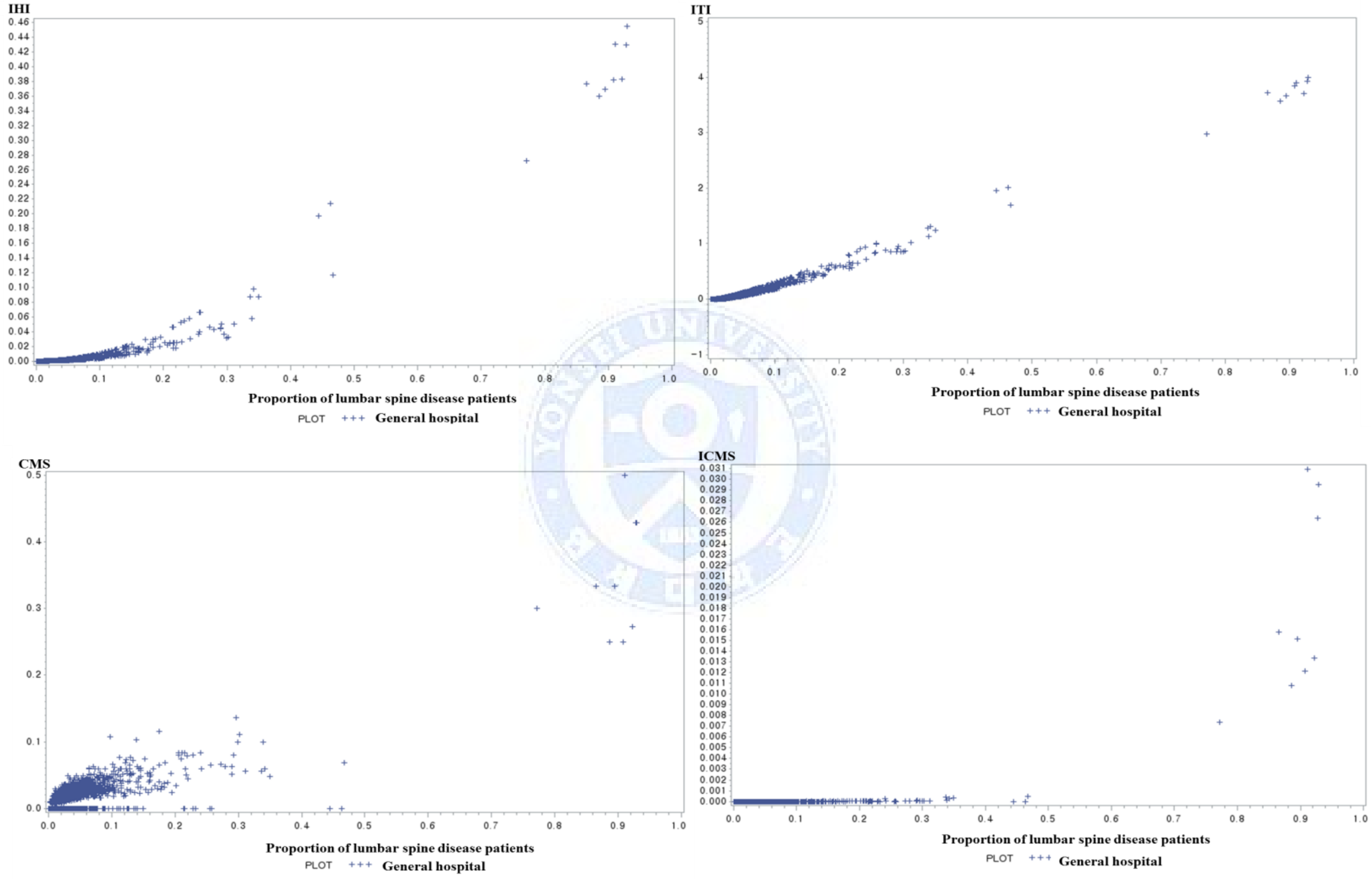
Appendix B2. Hospital specialization and proportion of lumbar spine disease patients among total hospital



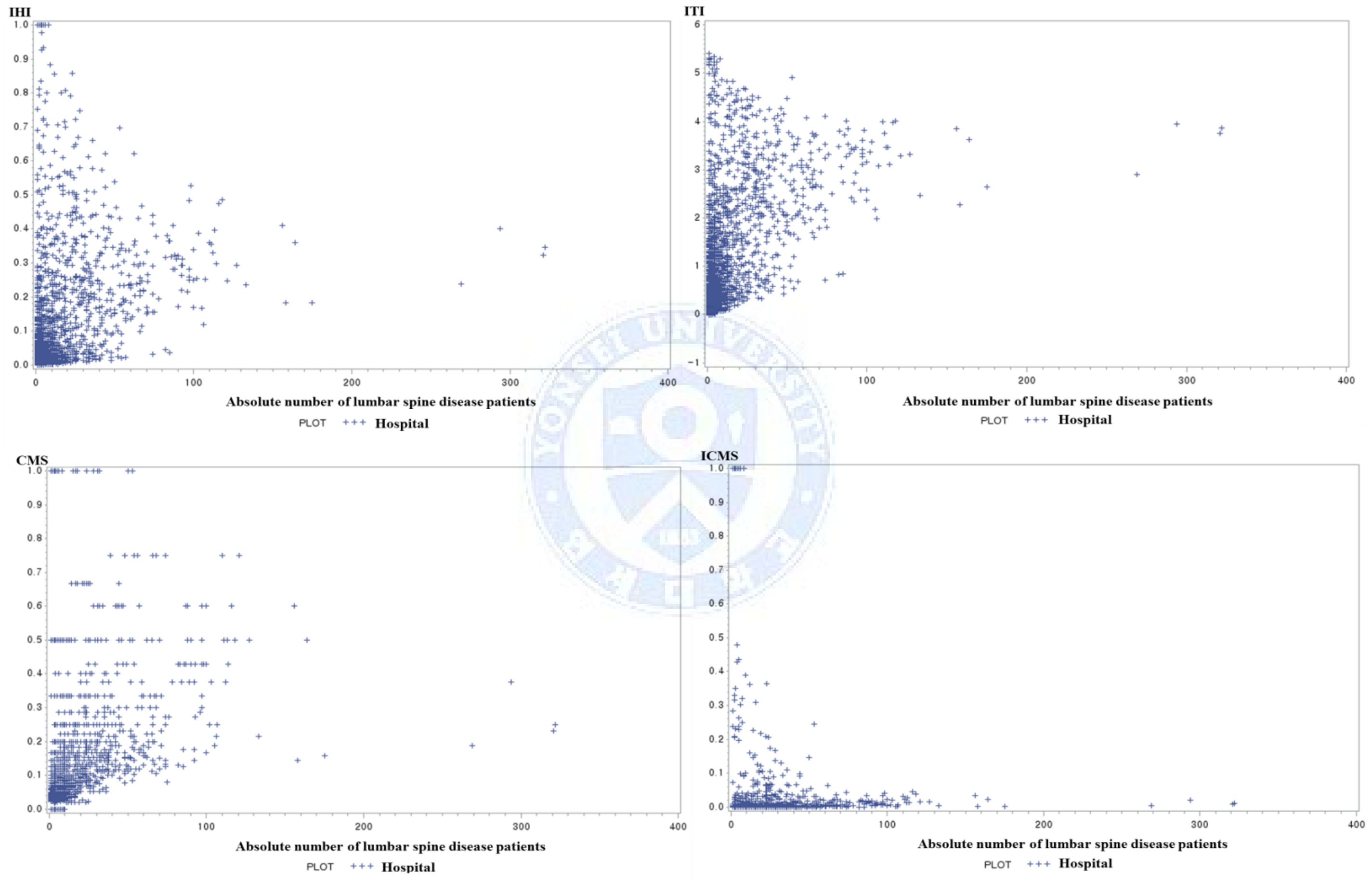
Appendix B3. Hospital specialization and absolute number of lumbar spine disease patients among general hospital



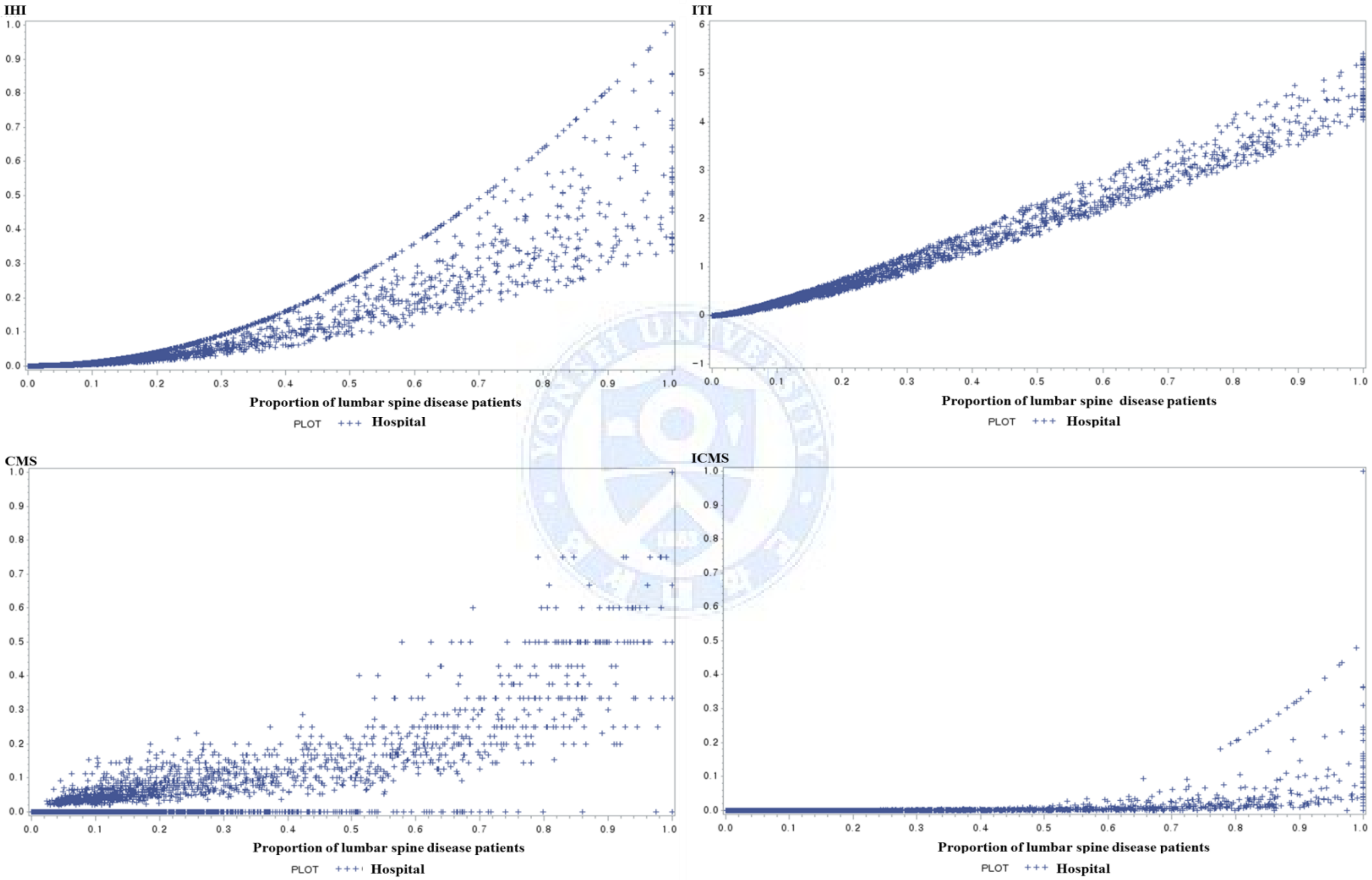
Appendix B4. Hospital specialization and proportion of lumbar spine disease patients among general hospital



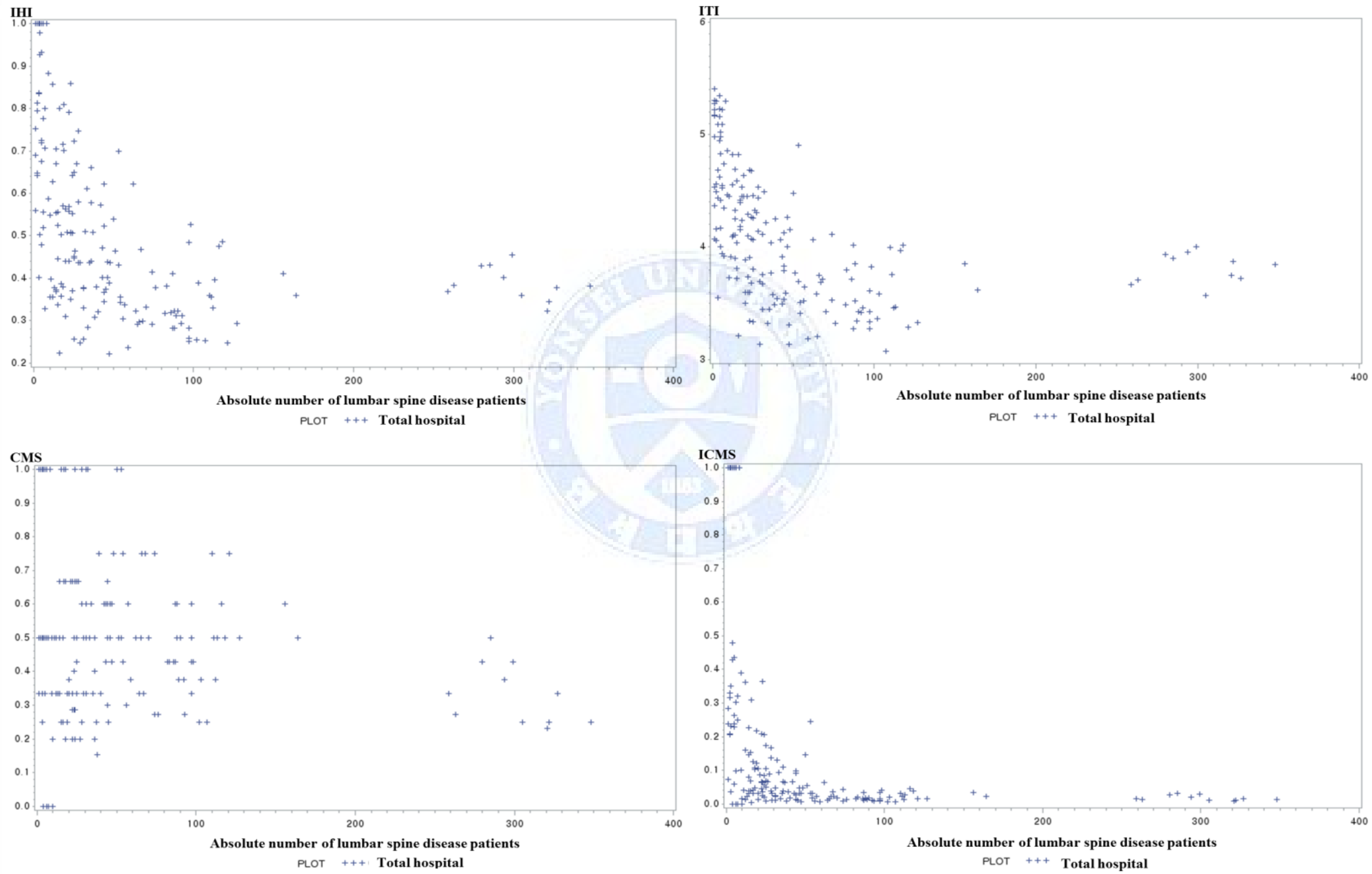
Appendix B5. Hospital specialization and absolute number of lumbar spine disease patients among hospital



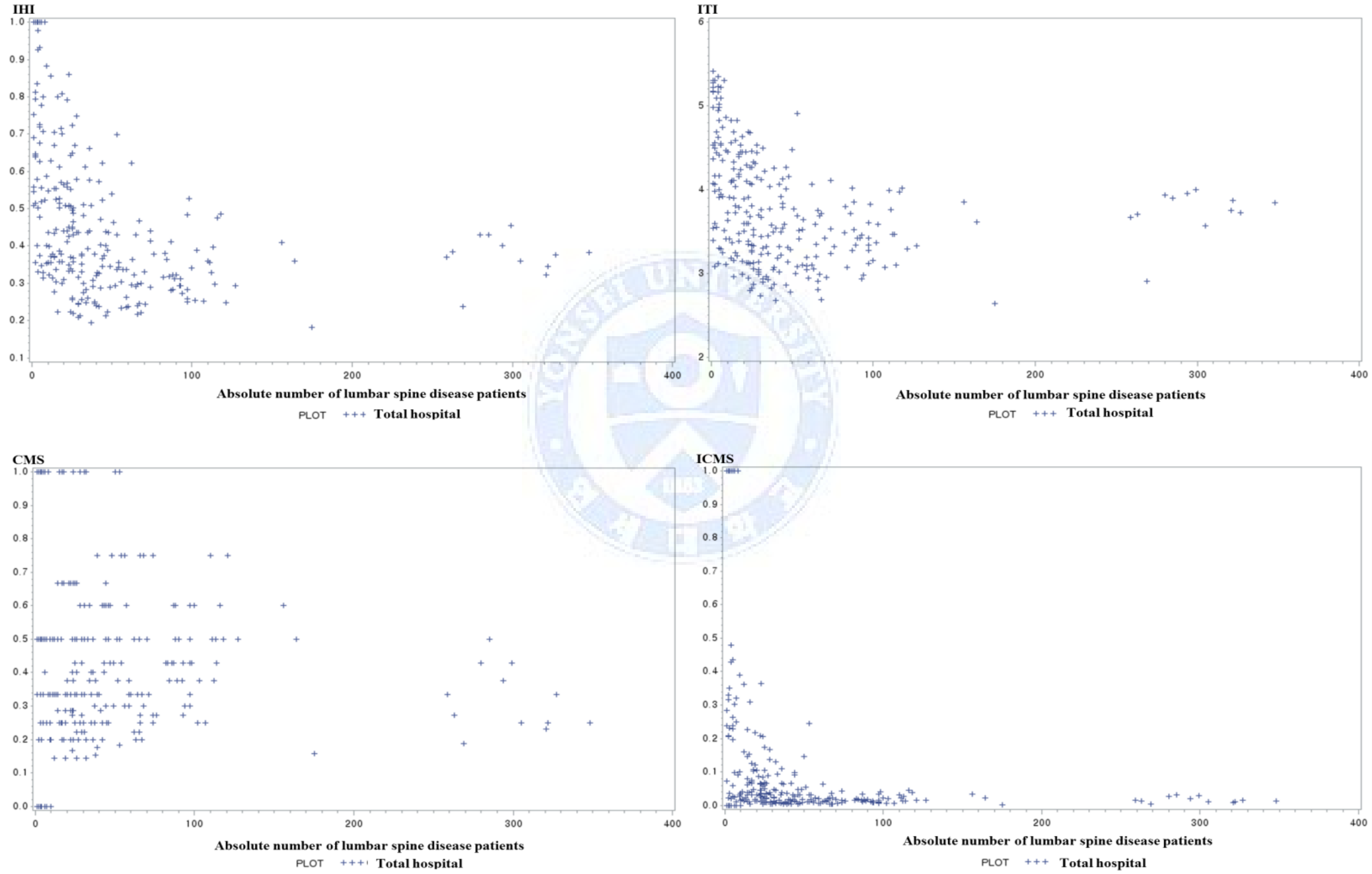
Appendix B6. Hospital specialization and proportion of lumbar spine disease patients among hospital



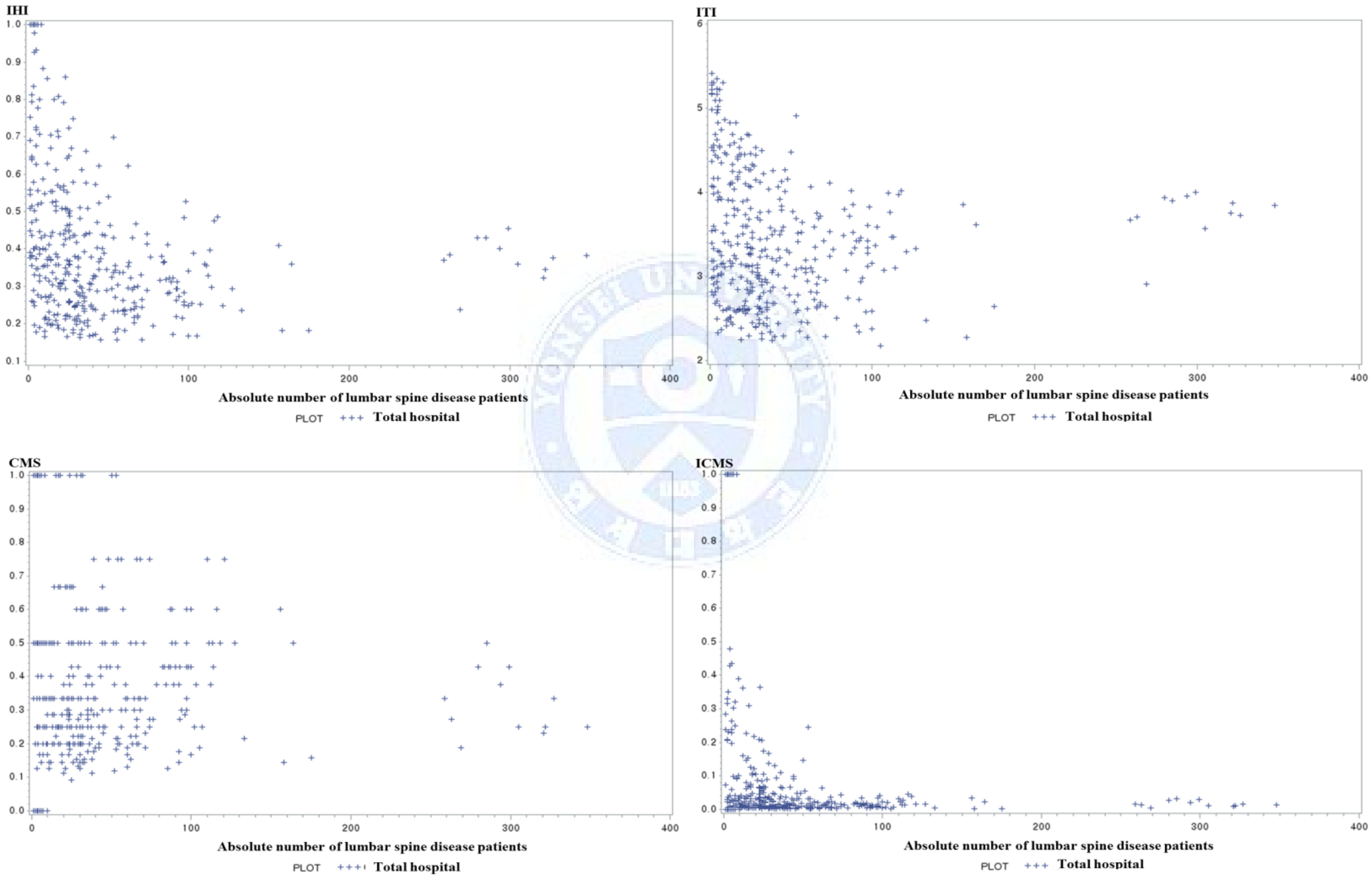
Appendix C1. Hospital specialization and absolute number of lumbar spine disease patients among ≥80% hospitals of lumbar spine disease patients for total patients



Appendix C2. Hospital specialization and absolute number of lumbar spine disease patients among ≥70% hospitals of lumbar spine disease patients for total patients



Appendix C3. Hospital specialization and absolute number of lumbar spine disease patients among ≥60% hospitals of lumbar spine disease patients for total patients



Appendix D1. Comparison of goodness of fit by hospital specialization index among Cluster 1

	Length of stay					Total cost per case					Total cost per diem				
	Estimate	95% CI		P-value	QIC	Estimate	95% CI		P-value	QIC	Estimate	95% CI		P-value	QIC
Total patients															
IHI	-2.598	-5.612	0.415	0.091	22,348.8	207,117	-400,640	814,873	0.504	22,461.3	117,293	26,942	207,644	0.011	22,015.5
ITI	-0.482	-0.889	-0.075	0.020	22,348.1	67,660	-17,946	153,266	0.121	22,461.5	21,923	9,298	34,548	0.001	22,014.8
CMS	-6.211	-8.405	-4.017	<.0001	22,346.3	329,602	-529,658	1,188,862	0.452	22,461.5	222,204	95,968	348,440	0.001	22,016.5
ICMS	-1.871	-6.378	2.636	0.410	22,342.8	-402,293	-2,166,110	1,361,523	0.655	22,460.6	259,419	-1,170	520,008	0.051	22,026.2
Modified CMS	-1.345	-1.890	-0.799	<.0001	22,345.6	414,544	200,962	628,127	0.000	22,462.8	71,710	40,306	103,113	<.0001	22,014.8
Surgery patients															
IHI	-2.893	-5.930	0.143	0.062	8,427.7	301,669	-1,082,742	1,686,080	0.669	8,512.7	165,829	29,175	302,482	0.017	8,402.4
ITI	-0.663	-1.065	-0.262	0.001	8,426.7	62,639	-120,697	245,976	0.503	8,512.4	27,155	9,061	45,249	0.003	8,402.4
CMS	-9.982	-13.863	-6.100	<.0001	8,424.9	-682,999	-2,455,051	1,089,053	0.450	8,512.0	165,549	-9,395	340,493	0.064	8,402.4
ICMS	0.946	-8.867	10.760	0.850	8,421.2	-1,877,512	-6,350,625	2,595,601	0.411	8,510.2	-82,945	-524,636	358,746	0.713	8,401.4
Modified CMS	-2.649	-3.590	-1.708	<.0001	8,424.1	202,246	-227,488	631,979	0.356	8,513.0	82,323	39,917	124,728	0.000	8,402.9
non-Surgery patients															
IHI	-2.716	-4.505	-0.927	0.003	13,960.8	11,666	-596,531	619,863	0.970	13,974.4	105,096	-13,001	223,192	0.081	13,689.7
ITI	-0.439	-0.697	-0.181	0.001	13,960.6	48,292	-39,476	136,059	0.281	13,974.5	19,770	2,899	36,641	0.022	13,688.8
CMS	-4.677	-7.310	-2.044	0.001	13,959.9	743,121	-151,909	1,638,151	0.104	13,974.7	258,618	87,468	429,768	0.003	13,690.8
ICMS	-2.930	-7.931	2.071	0.251	13,958.6	-169,958	-1,869,544	1,529,629	0.845	13,975.5	387,222	60,340	714,104	0.020	13,700.3
Modified CMS	-0.725	-1.407	-0.043	0.037	13,957.8	518,598	293,123	744,072	<.0001	13,974.8	67,412	24,212	110,611	0.002	13,688.6

***Adjusted for all variables**

Appendix D2. Comparison of goodness of fit by hospital specialization index among Cluster 2

	Length of stay					Total cost per case					Total cost per diem				
	Estimate	**95% CI**		**P-value**	**QIC**	**Estimate**	**95% CI**		**P-value**	**QIC**	**Estimate**	**95% CI**		**P-value**	**QIC**
Total patients															
IHI	1.911	-0.748	4.570	0.159	12,193.5	922,760	108,664	1,736,856	0.026	12,472.0	156,816	2,722	310,909	0.046	12,053.1
ITI	0.627	0.196	1.057	0.004	12,193.8	454,504	322,904	586,104	<.0001	12,474.2	47,359	29,738	64,979	<.0001	12,054.3
CMS	2.730	-0.070	5.530	0.056	12,193.4	1,991,751	1,134,874	2,848,628	<.0001	12,472.6	191,151	76,966	305,336	0.001	12,051.3
ICMS	1.373	-1.606	4.351	0.367	12,193.1	-29,824	-942,066	882,418	0.949	12,471.6	5,405	-82,313	93,123	0.904	12,050.3
Modified CMS	2.387	1.320	3.455	<.0001	12,192.7	2,317,501	1,993,025	2,641,978	<.0001	12,474.3	186,397	142,795	229,999	<.0001	12,050.7
Surgery patients															
IHI	-4.303	-9.735	1.128	0.120	2,758.6	1,032,215	-1,291,190	3,355,621	0.384	2,921.9	61,931	-94,831	218,692	0.439	3,009.0
ITI	-0.565	-1.574	0.445	0.273	2,759.0	730,624	314,776	1,146,471	0.001	2,923.5	40,750	12,674	68,826	0.004	3,011.0
CMS	-2.331	-8.057	3.395	0.425	2,758.3	1,933,083	-429,805	4,295,971	0.109	2,921.9	102,102	-57,348	261,553	0.210	3,009.0
ICMS	-2.979	-8.890	2.931	0.323	2,758.2	-452,948	-2,893,288	1,987,392	0.716	2,921.6	-47,403	-212,048	117,242	0.573	3,008.8
Modified CMS	1.892	-0.786	4.571	0.166	2,759.5	3,595,538	2,498,429	4,692,647	<.0001	2,922.7	233,288	159,178	307,398	<.0001	3,008.0
non-Surgery patients															
IHI	3.745	0.701	6.790	0.016	9,505.0	793,375	75,216	1,511,534	0.030	9,504.2	187,842	50,731	324,952	0.007	9,372.2
ITI	0.873	0.399	1.347	0.000	9,505.2	332,703	221,050	444,356	<.0001	9,504.7	47,634	26,276	68,993	<.0001	9,373.6
CMS	4.089	0.831	7.348	0.014	9,505.0	1,804,245	1,036,272	2,572,217	<.0001	9,504.7	208,658	62,618	354,698	0.005	9,369.9
ICMS	2.846	-0.679	6.370	0.114	9,504.9	45,893	-785,657	877,444	0.914	9,504.0	7,860	-149,962	165,682	0.922	9,368.2
Modified CMS	2.206	1.056	3.357	0.000	9,505.6	1,757,050	1,487,736	2,026,365	<.0001	9,503.7	163,651	111,917	215,385	<.0001	9,371.4

***Adjusted for all variables**

Appendix D3. Comparison of goodness of fit by hospital specialization index among Cluster 3

	Length of stay					Total cost per case					Total cost per diem				
	Estimate	95% CI		P-value	QIC	Estimate	95% CI		P-value	QIC	Estimate	95% CI		P-value	QIC
Total patients															
IHI	3.118	2.330	3.907	<.0001	22,438.2	775,480	484,071	1,066,888	<.0001	22,755.3	39	-42,415	42,493	0.999	22,293.3
ITI	0.548	0.418	0.678	<.0001	22,438.2	225,680	135,748	315,611	<.0001	22,755.6	7,809	801	14,817	0.029	22,293.7
CMS	0.688	0.055	1.320	0.033	22,437.8	502,235	268,678	735,792	<.0001	22,756.5	22,011	-11,989	56,011	0.205	22,294.3
ICMS	5.832	3.578	8.085	<.0001	22,436.6	-47,788	-880,314	784,739	0.910	22,753.5	-86,263	-207,407	34,881	0.163	22,292.0
Modified CMS	-0.068	-0.340	0.204	0.624	22,437.3	240,746	140,364	341,127	<.0001	22,755.4	18,575	3,970	33,179	0.013	22,291.6
Surgery patients															
IHI	3.857	2.514	5.200	<.0001	10,582.3	1,242,626	730,490	1,754,762	<.0001	10,704.5	-791	-59,957	58,375	0.979	10,578.3
ITI	0.657	0.440	0.873	<.0001	10,582.0	318,873	236,311	401,436	<.0001	10,703.4	12,366	2,814	21,918	0.011	10,577.6
CMS	1.240	0.245	2.234	0.015	10,581.5	852,564	473,879	1,231,249	<.0001	10,703.4	29,712	-14,038	73,462	0.183	10,579.5
ICMS	7.389	2.887	11.892	0.001	10,580.6	728,330	-988,717	2,445,378	0.406	10,704.0	-211,731	-409,840	-13,622	0.036	10,578.0
Modified CMS	0.208	-0.224	0.640	0.346	10,580.2	361,853	197,265	526,442	<.0001	10,702.7	21,008	1,998	40,018	0.030	10,578.7
non-Surgery patients															
IHI	2.158	1.231	3.086	<.0001	11,853.2	224,901	-82,578	532,380	0.152	11,871.9	385	-60,135	60,904	0.990	11,771.6
ITI	0.378	0.222	0.533	<.0001	11,853.1	105,152	53,623	156,682	<.0001	11,872.2	5,194	-4,952	15,339	0.316	11,772.3
CMS	0.086	-0.706	0.879	0.831	11,852.8	121,126	-141,363	383,616	0.366	11,872.2	22,142	-29,497	73,781	0.401	11,771.6
ICMS	4.884	2.443	7.326	<.0001	11,853.7	-471,592	-1,280,999	337,814	0.254	11,871.6	-55,120	-214,217	103,977	0.497	11,770.8
Modified CMS	-0.336	-0.672	0.000	0.050	11,852.6	115,400	4,076	226,723	0.042	11,872.0	19,955	-1,921	41,831	0.074	11,770.4

***Adjusted for all variables**

Appendix E1. Adjusted effect between Modified CMS and LOS among non-surgery patients

		Length of Stay			
		Estimate	95% CI		P-value
Hospital level					
Modified CMS		-1.269	-1.497	-1.041	<.0001
Type					
	Tertiary Hospital	1.587	0.953	2.221	<.0001
	General Hospital	1.358	0.987	1.729	<.0001
	Hospital	ref			
Organization Type					
	Public	0.890	0.090	1.689	0.029
	Corporate	0.698	0.419	0.977	<.0001
	Private	ref			
Region					
	Metropolitan	-1.210	-1.518	-0.903	<.0001
	Urban	1.641	1.327	1.955	<.0001
	Rural	ref			
Bed					
	≤199	-1.461	-2.427	-0.495	0.003
	200-299	-1.204	-2.126	-0.282	0.011
	300-399	-0.386	-1.329	0.558	0.423
	400-499	-1.563	-2.555	-0.571	0.002
	500-599	0.728	-0.165	1.620	0.110
	600-699	0.593	-0.259	1.444	0.172
	700-799	0.300	-0.520	1.120	0.473
	800-899	2.072	1.335	2.809	<.0001
	≥900	ref			
Doctor					
	≤49	1.957	0.975	2.938	<.0001
	50-99	0.486	-0.472	1.444	0.320
	100-149	0.689	-0.247	1.624	0.149
	150-199	0.489	-0.375	1.353	0.267
	200-249	-0.187	-1.000	0.627	0.653
	250-299	0.132	-0.561	0.826	0.708
	≥300	ref			
CT					
	No	0.106	-0.341	0.553	0.642
	Yes	ref			
MRI					
	No	1.470	1.089	1.851	<.0001
	Yes	ref			
PET					
	No	1.483	1.014	1.952	<.0001
	Yes	ref			
Individual level					
PCCL					
	0	-6.708	-7.503	-5.914	<.0001
	1	-3.417	-4.228	-2.607	<.0001
	2	-1.849	-2.688	-1.011	<.0001
	3	ref			
Sex					
	Male	-0.631	-0.823	-0.438	<.0001
	Female	ref			
Age					
	≤29	-2.052	-2.475	-1.630	<.0001
	30-39	-1.834	-2.204	-1.464	<.0001
	40-49	-1.103	-1.443	-0.763	<.0001
	50-59	-0.398	-0.712	-0.083	0.013
	60-69	0.323	0.008	0.638	0.044
	≥70	ref			
Region					
	Metropolitan	-0.095	-0.405	0.214	0.546
	Urban	-0.189	-0.495	0.118	0.228
	Rural	ref			
Death					
	Yes	ref			
	No	1.691	0.506	2.877	0.005
Year					
	2002	3.786	3.122	4.451	<.0001
	2003	3.883	3.291	4.475	<.0001
	2004	2.493	1.947	3.039	<.0001
	2005	2.419	1.932	2.907	<.0001
	2006	2.988	2.523	3.453	<.0001
	2007	2.854	2.417	3.290	<.0001
	2008	2.890	2.484	3.296	<.0001
	2009	2.837	2.448	3.227	<.0001
	2010	1.886	1.515	2.258	<.0001

2011	0.725	0.376	1.074	<.0001
2012	0.397	0.062	0.732	0.020
2013	ref			

Adjusted for primary diagnosed code

Appendix E2. Adjusted effect between Modified CMS and mortality among non-surgery patients

		Mortality			
		OR	95% CI		P-value
Hospital level					
Modified CMS		0.552	0.428	0.712	<.0001
Type					
	Tertiary Hospital	0.925	0.536	1.596	0.778
	General Hospital	0.803	0.575	1.122	0.199
	Hospital	1.000			
Organization Type					
	Public	2.100	1.315	3.355	0.002
	Corporate	1.255	0.975	1.616	0.077
	Private	1.000			
Region					
	Metropolitan	0.927	0.680	1.263	0.629
	Urban	1.098	0.828	1.456	0.514
	Rural	1.000			
Bed					
	≤199	1.388	0.547	3.519	0.490
	200-299	1.565	0.636	3.852	0.330
	300-399	1.414	0.569	3.513	0.455
	400-499	1.272	0.497	3.253	0.615
	500-599	1.220	0.516	2.884	0.651
	600-699	0.891	0.388	2.044	0.785
	700-799	0.996	0.445	2.228	0.991
	800-899	0.798	0.403	1.583	0.519
	≥900	1.000			
Doctor					
	≤49	0.560	0.219	1.434	0.227
	50-99	0.586	0.240	1.434	0.242
	100-149	0.641	0.267	1.539	0.320
	150-199	0.327	0.125	0.854	0.023
	200-249	0.476	0.207	1.096	0.081
	250-299	1.009	0.590	1.725	0.974
	≥300	1.000			
CT					
	No	0.924	0.581	1.469	0.737
	Yes	1.000			
MRI					
	No	1.605	1.200	2.146	0.002
	Yes	1.000			
PET					
	No	0.959	0.614	1.499	0.854
	Yes	1.000			
Individual level					
PCCL					
	0	0.184	0.134	0.252	<.0001
	1	0.243	0.174	0.340	<.0001
	2	0.350	0.249	0.491	<.0001
	3	1.000			
Sex					
	Male	1.626	1.354	1.952	<.0001
	Female	1.000			
Age					
	≤29	0.116	0.065	0.206	<.0001
	30-39	0.123	0.078	0.195	<.0001
	40-49	0.136	0.092	0.201	<.0001
	50-59	0.193	0.143	0.262	<.0001
	60-69	0.315	0.246	0.404	<.0001
	≥70	1.000			
Region					
	Metropolitan	0.861	0.622	1.194	0.369
	Urban	0.972	0.733	1.289	0.841
	Rural	1.000			
Death					
	Yes		N/A		
	No				
Year					
	2002	0.526	0.180	1.537	0.240
	2003	1.511	0.853	2.678	0.157
	2004	1.126	0.659	1.923	0.664
	2005	1.100	0.677	1.786	0.700
	2006	1.492	0.969	2.299	0.070
	2007	1.435	0.948	2.172	0.087
	2008	1.187	0.790	1.785	0.410
	2009	1.458	1.006	2.114	0.046
	2010	1.374	0.952	1.984	0.090
	2011	1.165	0.813	1.671	0.406
	2012	1.307	0.931	1.835	0.122
	2013	1.000			

Adjusted for primary diagnosed code

Appendix E3. Adjusted effect between Modified CMS and total cost among non-surgery patients

		Total Cost per case			
		Estimate	95% CI		P-value
Hospital level					
Modified CMS		353,831	285,466	422,196	<.0001
Type					
	Tertiary Hospital	354,570	164,792	544,348	0.000
	General Hospital	149,797	38,700	260,895	0.008
	Hospital	ref			
Organization Type					
	Public	-236,173	-475,587	3,241	0.053
	Corporate	-7,227	-90,891	76,437	0.866
	Private	ref			
Region					
	Metropolitan	165,535	73,471	257,599	0.000
	Urban	326,657	232,605	420,709	<.0001
	Rural	ref			
Bed					
	≤199	-85,641	-374,788	203,506	0.562
	200-299	4,656	-271,414	280,726	0.974
	300-399	156,898	-125,551	439,348	0.276
	400-499	60,278	-236,759	357,314	0.691
	500-599	504,949	237,711	772,187	0.000
	600-699	542,585	287,688	797,482	<.0001
	700-799	271,660	26,138	517,181	0.030
	800-899	342,380	121,667	563,093	0.002
	≥900	ref			
Doctor					
	≤49	-827,783	-1,121,751	-533,815	<.0001
	50-99	-1,059,023	-1,345,901	-772,146	<.0001
	100-149	-543,746	-823,842	-263,650	0.000
	150-199	-493,576	-752,246	-234,907	0.000
	200-249	-566,704	-810,112	-323,297	<.0001
	250-299	-417,086	-624,601	-209,572	<.0001
	≥300	ref			
CT					
	No	-95,965	-229,771	37,841	0.160
	Yes	ref			
MRI					
	No	-263,461	-377,452	-149,470	<.0001
	Yes	ref			
PET					
	No	-10,809	-151,240	129,622	0.880
	Yes	ref			
Individual level					
PCCL					
	0	-950,431	-1,188,266	-712,596	<.0001
	1	-56,520	-299,174	186,133	0.648
	2	306,877	55,904	557,850	0.017
	3	ref			
Sex					
	Male	-4,023	-61,660	53,615	0.891
	Female	ref			
Age					
	≤29	-679,533	-805,987	-553,078	<.0001
	30-39	-567,959	-678,783	-457,134	<.0001
	40-49	-394,721	-496,558	-292,884	<.0001
	50-59	-151,006	-245,066	-56,946	0.002
	60-69	248,133	153,916	342,350	<.0001
	≥70	ref			
Region					
	Metropolitan	-76,867	-169,607	15,873	0.104
	Urban	-126,665	-218,390	-34,940	0.007
	Rural	ref			
Death					
	Yes	ref			
	No	724,384	369,419	1,079,348	<.0001
Year					
	2002	409,647	210,692	608,602	<.0001
	2003	293,676	116,463	470,888	0.001
	2004	-3,782	-167,169	159,605	0.964
	2005	142,691	-3,351	288,733	0.056
	2006	235,791	96,655	374,927	0.001
	2007	430,145	299,475	560,816	<.0001
	2008	365,446	243,941	486,952	<.0001
	2009	469,402	352,894	585,911	<.0001
	2010	379,202	268,037	490,367	<.0001
	2011	117,825	13,284	222,366	0.027
	2012	68,619	-31,706	168,944	0.180
	2013	ref			

Adjusted for primary diagnosed code

Appendix E4. Adjusted effect between Modified CMS and total cost per diem among non-surgery patients

		Total Cost per diem			
		Estimate	95% CI		P-value
Hospital level					
Modified CMS		61,843	48,797	74,888	<.0001
Type					
	Tertiary Hospital	64,088	27,545	100,631	0.001
	General Hospital	17,356	-3,902	38,614	0.110
	Hospital	ref			
Organization Type					
	Public	-45,381	-91,209	447	0.052
	Corporate	-15,900	-31,909	109	0.052
	Private	ref			
Region					
	Metropolitan	40,337	22,713	57,961	<.0001
	Urban	3,661	-14,354	21,675	0.690
	Rural	ref			
Bed					
	≤199	-39,325	-94,866	16,217	0.165
	200-299	-13,283	-66,335	39,770	0.624
	300-399	-35,480	-89,767	18,807	0.200
	400-499	-12,040	-69,204	45,124	0.680
	500-599	17,648	-33,662	68,958	0.500
	600-699	36,255	-12,750	85,261	0.147
	700-799	-35,928	-83,348	11,493	0.138
	800-899	-15,445	-57,629	26,739	0.473
	≥900	ref			
Doctor					
	≤49	-52,332	-108,925	4,261	0.070
	50-99	-40,637	-95,840	14,567	0.149
	100-149	-44,740	-98,532	9,052	0.103
	150-199	-34,750	-84,517	15,017	0.171
	200-249	-41,535	-88,302	5,232	0.082
	250-299	-31,330	-71,178	8,518	0.123
	≥300	ref			
CT					
	No	-22,928	-48,481	2,625	0.079
	Yes	ref			
MRI					
	No	-14,068	-35,874	7,739	0.206
	Yes	ref			
PET					
	No	-3,813	-30,903	23,277	0.783
	Yes	ref			
Individual level					
PCCL					
	0	41,396	-4,460	87,252	0.077
	1	51,470	4,694	98,246	0.031
	2	59,784	11,421	108,147	0.015
	3	ref			
Sex					
	Male	15,689	4,655	26,722	0.005
	Female	ref			
Age					
	≤29	-39,029	-63,208	-14,849	0.002
	30-39	-40,723	-61,945	-19,501	0.000
	40-49	-26,671	-46,182	-7,160	0.007
	50-59	-11,098	-29,129	6,932	0.228
	60-69	11,315	-6,738	29,367	0.219
	≥70	ref			
Region					
	Metropolitan	-11,930	-29,680	5,819	0.188
	Urban	-8,108	-25,661	9,446	0.365
	Rural	ref			
Death					
	Yes	ref			
	No	-4,127	-72,108	63,853	0.905
Year					
	2002	-4,691	-42,568	33,185	0.808
	2003	-27,952	-61,708	5,803	0.105
	2004	3,580	-27,544	34,703	0.822
	2005	2,998	-24,874	30,871	0.833
	2006	-14,760	-41,319	11,799	0.276
	2007	5,123	-19,799	30,046	0.687
	2008	9,818	-13,366	33,001	0.407
	2009	7,394	-14,822	29,611	0.514
	2010	-2,173	-23,367	19,020	0.841
	2011	1,018	-19,224	21,261	0.922
	2012	13,057	-6,101	32,214	0.182
	2013	ref			

Adjusted for primary diagnosed code

Appendix E5. Adjusted effect between Modified CMS and health care cost per case components among non-surgery patients by hospital type

	Total hospital				≥ General hospital				Hospital			
	Estimate	95% CI		P-value	Estimate	95% CI		P-value	Estimate	95% CI		P-value
non-Surgery patients												
Admission cost per case	10,502	-9,808	30,811	0.311	15,208	-53,558	83,974	0.665	10,381	-7,194	27,956	0.247
Medication cost per case	8,522	5,387	11,658	<.0001	12,277	1,408	23,147	0.027	7,841	5,240	10,442	<.0001
Injection cost per case	11,054	-1,048	23,157	0.073	42,957	2,575	83,340	0.037	7,832	-2,878	18,542	0.152
Anesthesia cost per case	35,249	31,246	39,251	<.0001	58,689	46,614	70,763	<.0001	28,624	24,613	32,634	<.0001
Procedure or surgery cost per case	280,996	241,263	320,729	<.0001	424,856	299,354	550,357	<.0001	251,417	213,642	289,192	<.0001
Examination cost per case	7,508	2,461	12,554	0.004	12,102	-6,769	30,974	0.209	7,101	3,679	10,523	<.0001

***Adjusted for all variables**

Appendix E6. Adjusted effect between Modified CMS and health care cost per diem components among non-surgery patients by hospital type

	Total hospital				≥ General hospital				Hospital			
	Estimate	95% CI		P-value	Estimate	95% CI		P-value	Estimate	95% CI		P-value
non-Surgery patients												
Admission cost per diem	6,101	2,254	9,948	0.002	12,600	-1,166	26,365	0.073	4,932	1,874	7,991	0.002
Medication cost per diem	1,833	1,289	2,376	<.0001	2,975	1,039	4,911	0.003	1,672	1,236	2,108	<.0001
Injection cost per diem	3,698	1,939	5,458	<.0001	6,433	184	12,682	0.044	3,289	1,871	4,707	<.0001
Anesthesia cost per diem	5,346	4,476	6,216	<.0001	9,313	6,338	12,288	<.0001	4,154	3,406	4,903	<.0001
Procedure or surgery cost per diem	43,485	36,259	50,710	<.0001	63,863	40,034	87,692	<.0001	38,470	31,885	45,055	<.0001
Examination cost per diem	1,380	93	2,667	0.036	4,946	-140	10,031	0.057	943	200	1,685	0.013

***Adjusted for all variables**

Korean Abstract

병원 전문화 지수와 건당 의료비, 일당 의료비, 사망률, 재원일수
-요추질환 입원환자를 중심으로-

김재현

서론: 한국은 최근 경제불황과 전향적 지불제도(Diagnosis related group, DRG)를 도입함에 따라 병원들간의 경쟁이 치열해지면서 환자들로 하여금 더 많은 수익을 얻고, 다른 병원들과 비교우위를 위해 전문화 전략을 택하기 시작하였다. 전문화 전략은 다른 병원들과 비교우위를 위한 차별화 전략과 집중화 전략으로서 병원들로 하여금 진료방식의 변화를 이끌어 내었다. 최근 한국은 양질의 수준 높은 진료와 효율적인 의료를 환자에게 제공하기 위해 전문병원을 지정하여, 이들 병원들에게 인센티브를 제공함으로써 병원들로 하여금 변화를 이끌어내기 시작하였다. 이에 따라 많은 연구자들은 이러한 병원들의 전문화 수준을 측정하기 위해, 다양한 병원 전문화 지수 측정 방법론을 개발하였지만, 그럼에도 불구하고 여전히 기존 병원 전문화 지수는 병원 내 특정 진료과목의 전문화 지수를 측정하지 못하는 한계를 가지고 있다. 따라서 이 연구의 목적은 진단군별 의료전문화 지수의 변형을 통해, 요추환자의 건당 의료비, 일당 의료비, 사망률, 재원일수에 대한 효과를 보고자 하는 것이다.

연구 방법: 이 연구는 2002년부터 2013년까지 국민건강보험공단 표본코호트 자료를 이용하여 분석하였다. 수정된 진단군별 의료전문화 지수(modified CMS) 산출을 위해, 전체 병원 환자를 22개로 나눈 기존 진단군별 전문화 지수(CMS)를 한국질병분류 중분류인 267개로 세분화하고, 진단군별 전문화지수(CMS) 산출방식의 분모에 자연로그를 적용하여, 요추환자에 대한 병원 전문화 지수를 산출하였다. 분석에 포함된 건은 총 56,622건이며, 연간 1건이상의 요추입원환자 병원을 대상을 하였다. 통계분석방법은 개인수준과 병원수준을 동시에 고려한 일반화 추정방정식 모형(Generalized Estimating Equations, GEE)을 이용하였다.

연구 결과: 병원 내 요추환자에 대한 수정된 진단군별 의료전문화 지수(modified CMS)에 대해 병상수별, 병원종별에 따라 지수를 도식화해 본 결과 수정된 진단군별 의료전문화 지수(modified CMS)를 제외한 허핀달-허쉬만 지수(IHI)와 정보이론지수(ITI), 진단군별 의료전문화 지수(CMS), 내부 진단군별 의료전문화지수(ICMS)의 경우 병원의 규모가 증가함에 따라

감소하는 전문화 수치를 보였으나, 수정된 진단군별 의료전문화 지수(modified CMS)의 경우 U자 곡선을 확인할 수 있었으며, 비교적 가장 우수한 모형적합도(QIC)를 보였다. 또한 수술환자에 대해 수정된 진단군별 의료전문화 지수를 일반화 추정방정식 모형을 이용하여 요추수술환자의 재원일수, 사망률, 건당 의료비, 일당 의료비와의 관계를 살펴본 결과 병원의 전문화 지수가 증가할수록 재원일수, 사망률, 건당 진료비는 감소하였으나, 일당진료비는 증가하는 것을 볼 수 있었다.

결론: 기존 전문화지수의 제한점을 보완한 수정된 진단군별 의료 전문화 지수(modified CMS)의 경우 병원이 전문화 될수록 의료의 질(재원일수, 사망률)과 병원의 효율성(건당 진료비)이 향상하는 것을 알 수 있었다. 따라서 정책결정자들은 증가하는 병원경쟁과, 의료비를 줄이기 위해 우리의 전문화 지수가 정책결정자들의 정책입안에 도움을 줄 수 있을 것이라 사료되며, 이 연구의 외적 타당도를 증가시키기 위해 추가적인 연구가 필요할 것이다.

핵심어: 병원, 전문화, 의료비, 재원일수, 사망, 효율성